RED STAR VOLUME 36

Yakovlev Yak-36, Yak-38 & Yak-41

The Soviet 'Jump Jets'

Yefim Gordon

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Original translation by Dmitriy and Sergey Komissarov

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Title page: The first prototype Yak-36 *sans suffixe*, '37 Yellow', hovers at Moscow-Domodedovo during the airshow on 9th July 1967.
This page: '27 Yellow', a production Yak-38, hovers above the Soviet aircraft carrier SNS *Kiev*.

Front cover: Yak-38 '71 Yellow' armed with cannon pods makes a short take-off from SNS *Novorossiysk*; note the position of the main engine nozzles.
Rear cover: Russian 'jump jets' at Farnborough in September 1992: Yak-38 '38 Yellow' in the static park together with other Russian types (top) and Yak-41 '141 White' taking off on a demo flight. The latter aircraft was demonstrated under the spurious designation Yak-141. *(Robert J. Ruffle)*

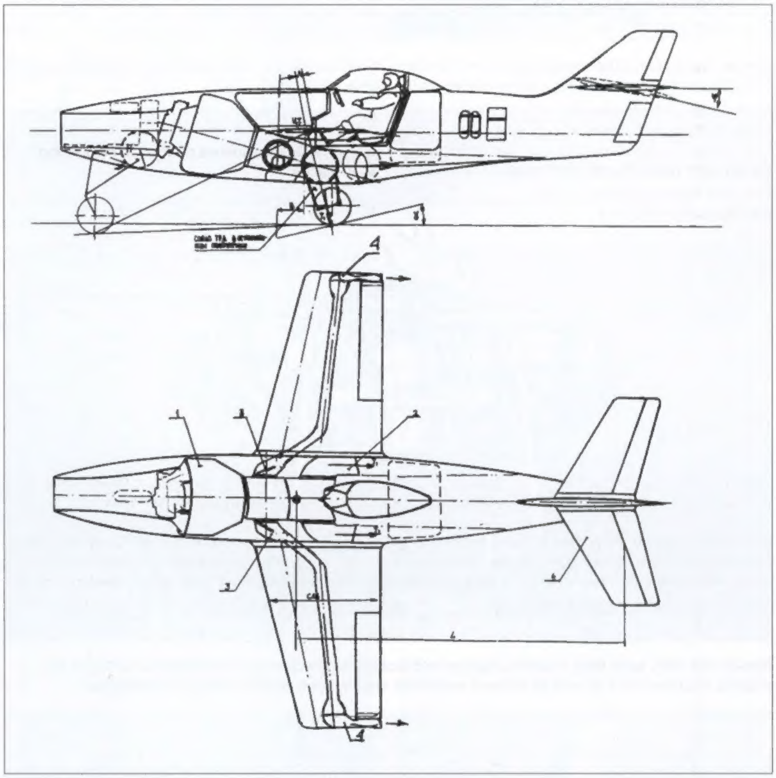
Introduction

Over the years, as aircraft grew increasingly more sophisticated and their payload, speed, service ceiling and range increased, the ground infrastructure also changed. Heavier and faster aircraft required larger airfields with longer runways, which became increasingly costly to build. Besides, a suitable location for a large airfield was not always available.

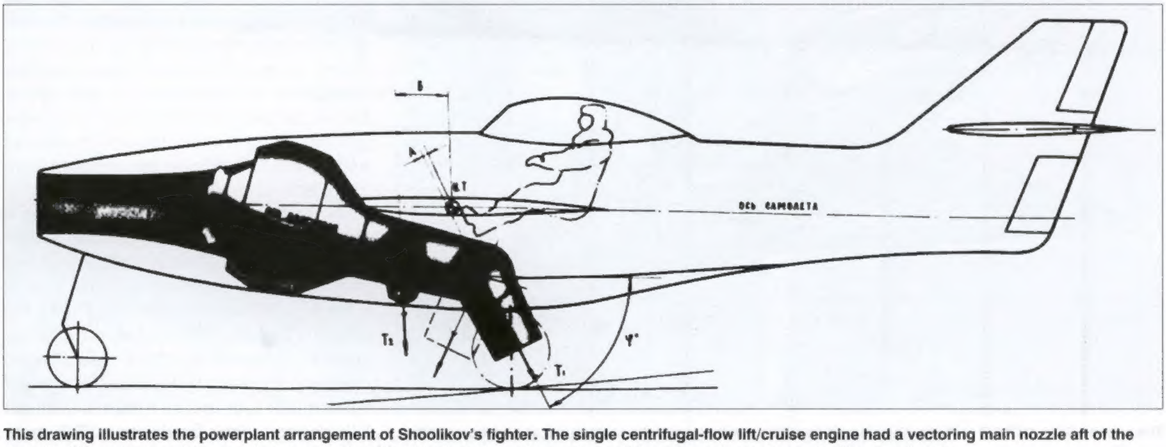
Therefore, as early as the 1950s aircraft designers started giving serious thought to improving the field performance of fixed-wing aircraft. The military on both sides of the 'Iron Curtain' posed a requirement for aircraft with short take-off and landing (STOL) and vertical take-off and landing (VTOL) capability which would be able to operate from short airstrips but still have high cruising speeds. In particular, such machines were eminently suitable for operation from aircraft carriers.

Few of the world's industrially developed nations could afford to create VTOL aircraft or even undertake research and development work in this field. The Soviet Union, with its huge financial resources and engineering talent, was one of them. Having a huge defence budget, it could not afford to lag behind the West in the development of such advanced weapons systems (pardon the pun).

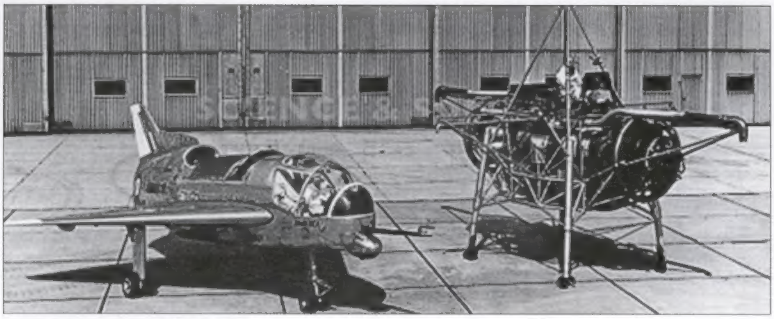
Fundamental research on V/STOL aircraft in the Soviet Union began as early as 1956-59. The first prerequisite for the creation of such aircraft was the availability of powerplants that would develop a thrust in excess of the aircraft's take-off weight.



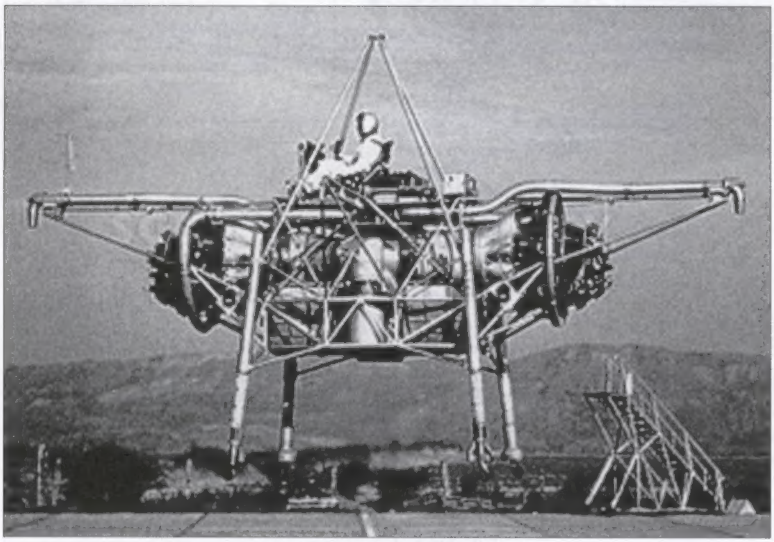
Above: This drawing shows a project of a V/STOL fighter proposed by the Soviet engineer K. V. Shoolikov. Note the wingtip reaction contol nozzles and the variable-incidence tailplane.



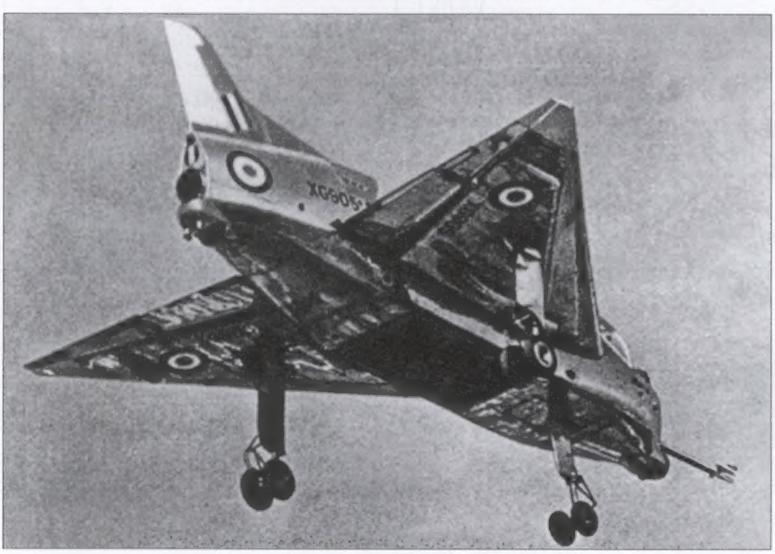
This drawing illustrates the powerplant arrangement of Shoolikov's fighter. The single centrifugal-flow lift/cruise engine had a vectoring main nozzle aft of the aircraft's CG and two auxiliary nozzles ahead of the CG. Note how the main nozzle could be vectored past the vertical for deceleration.



Above: Two British VTOL technology demonstrators – the Short SC.1 of 1957 (left) and the Rolls-Royce TMR (Thrust Measurement Rig), better known as the Flying Bedstead.



Above: The TMR, seen here hovering, was an odd-looking contraption by any standards, with two jet engines mounted back to back to exhaust amidships and reaction control puffers on outriggers.



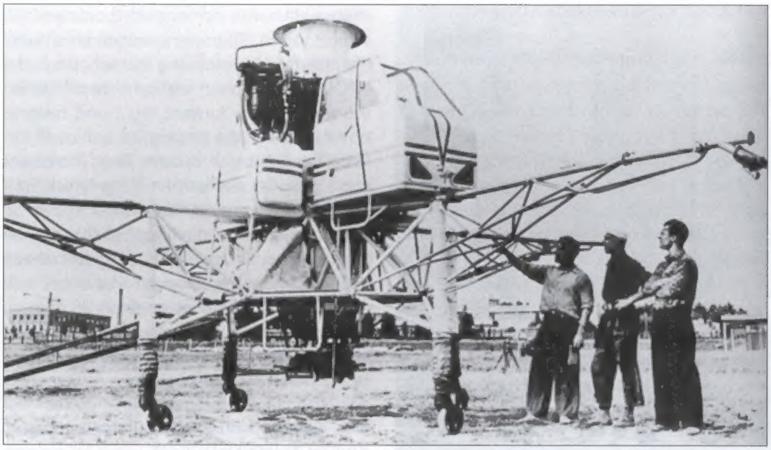
The second SC.1 (XG905) in flight, showing off its tailless-delta layout, the rectangular exhaust port of the four lift engines and the reaction control puffers under the nose, tail and wingtips.

Faced with the same task, engineers in different parts of the world often come up with the same solution. Thus, as early as 1947, when the Soviet Union had only just brought out its first-generation jet fighters, engineer K. V. Shoolikov (aka Pelenberg) working at the Mikoyan OKB suggested vectoring the thrust of jet engines by means of movable nozzles. Shoolikov obtained a Soviet patent for this invention, which would later be used in the Yakovlev Yak-36 and Yak-38. The same principle would later be used in the USA for the Bell X-14 (Type 68) VTOL technology demonstrator of 1957, in Great Britain for the Hawker P.1127 of 1960 which evolved into the well-known Hawker Siddeley (later British Aerospace) Harrier family of strike aircraft, and in West Germany for the VFW-Fokker VAK 191B (Focke-Wulf Fw 1262) experimental strike aircraft of 1963. Shoolikov also proposed a V/STOL fighter with a single turbojet engine in the forward fuselage.

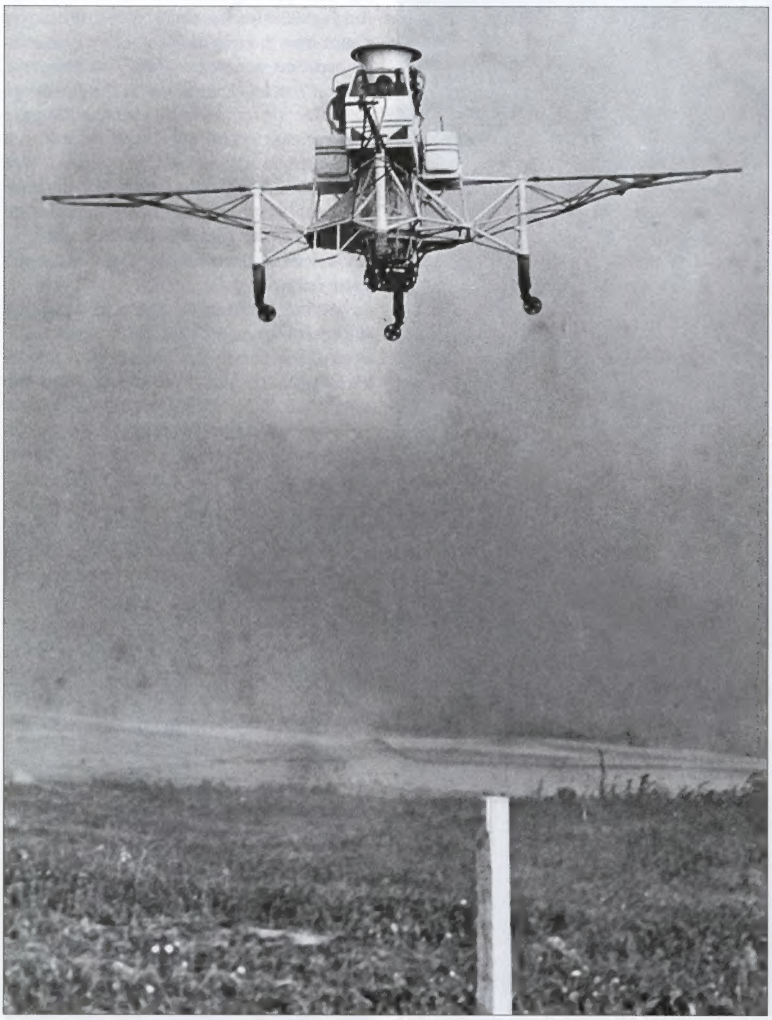
Next, the Soviet aircraft designer Aleksey Ya. Shcherbakov (known for the Shche-2 light transport aircraft of 1942) proposed a VTOL aircraft of a rather unusual layout:. Two turbojet engines were mounted in movable nacelles at the tips of low aspect ratio wings, tilting vertically to provide lift in take-off/landing mode. This was too bold a departure from conventional lines; Shcherbakov got far enough to start testing a scale model of the aircraft on a ground rig, but his opponents savaged the project and it was closed down. (The same principle was later used for the German EWR VJ-101C experimental VTOL aircraft of 1963 and the unbuilt Bell XF-109, which were viewed as successors to the Lockheed F-104 Starfighter.)

In 1955-56 the Flight Research Institute named after Mikhail M. Gromov (LII – *Lyo**tno**-is**sled**ovatel'skiy insti**toot***) located in the town of Zhukovskiy south of Moscow conducted several research programmes associated with VTOL technology. Among other things, a Mikoyan/Gurevich MiG-15 fighter was used as a research aircraft to investigate the low-speed control characteristics of an aircraft in vertical climb mode. The forward fuselage and Klimov VK-1A engine of a time-expired MiG-17 fighter was mounted vertically on a ground test rig to check the erosion effect of a VTOL aircraft's exhaust jets on paved (concrete) and unpaved runways.

Apart from the key issue of providing a thrust/weight ratio in excess of 1, the designers and engineers creating VTOL aircraft had numerous other problems to tackle. One of them was the need to ensure the aircraft's stability and controllability in the hover and at low speeds; conventional control surfaces were useless in these flight modes due to the insufficient dynamic pressure. Hence in 1955 the LII's design bureau developed a VTOL tech-



Above: The Soviet counterpart of the Flying Bedstead – the Rafaelyants Toorbolyot – looked just as outlandish with its vertical engine and outriggers.
Above right: The Toorbolyot makes a transition to forward flight.



Two more views of the Toorbolyot hovering. Note the funnel-like intake structure above the engine and the two fuel tanks flanking it.

Behold the magic dragon! The Toorbolyot performs at the 1958 Tushino air event.

nology demonstrator named *Toorbolyot* (lit. 'Turbo Flyer'). This was a unique aerial vehicle intended for exploring the behaviour of a VTOL aircraft during vertical take-off, hover, the transition to forward flight and back to hover, and vertical landing, as well as to forward speeds close to zero. The Toorbolyot was the Soviet counterpart of the British TMR (Thrust Measurement Rig), better known as the Flying Bedstead, though the two were totally different in layout. The programme was supervised by Vsevolod N. Matveyev, with Anatoliy I. Kvashnin as engineer in charge; Aram Nazarovich Rafaelyants headed the actual design effort, with the participation of designer G. N. Lapshin. Yuriy A. Garnayev was appointed the Toorbolyot's project test pilot, with G. I. Kobets as operations engineer.

The Toorbolyot was powered by a single Mikulin RD-9BP axial-flow turbojet (a special non-afterburning version of the RD-9B powering the MiG-19 supersonic fighter). In order to check how the engine would run in the vertical position (for which it was not designed, after all), a LII team under O. Konstantinov built a test rig representing a tetrahedral pyramid constructed of rolled steel beams on a concrete foundation. The engine was mounted vertically in the middle, and the base of the pyramid was rigged with temperature sensors. A test team headed by Sergey P. Shcherbakov undertook a series of experiments with this rig.

At first, a Klimov RD-45F centrifugal-flow turbojet from a MiG-15 was installed, the engine speed being controlled by a throttle via a long cable, which was later replaced with a hydraulic drive. For safety's sake the fuel tank was placed well away from the rig. Later, in the summer of 1956, the engine was substituted by the RD-9BF intended for the Toorbolyot. As mentioned earlier, this engine had the RD-9B's afterburner and the fuel system components pertaining thereto replaced by a simple fixed-area nozzle as a weight-saving measure.

The tests confirmed that the turbojet could run in the unaccustomed vertical position without any trouble. It was established that the exhaust jet fanned out uniformly in all directions like a thin veil upon hitting the ground rather than rising up like a billowing cloud. Thus the conditions were favourable for a vertical take-off.

The Toorbolyot had neither fuselage nor wings. The engine was perched on a welded steel truss with four vertical landing gear struts terminating in small castoring wheels and with four long outrigger booms of equal length at right angles to each other carrying reaction control nozzles. A small angular cockpit looking almost like the cab of a bulldozer was mounted on one side of the engine, featuring the usual flight controls – a

stick, rudder pedals (which belied their name because there was no rudder) and a throttle quadrant. The fuel was accommodated in two 200-litre (44 Imp gal) tanks flanking the engine.

The vehicle fitted into a 10 x 10 m (3 ft $3\frac{3}{8}$ in x 3 ft $3\frac{3}{8}$ in) square and was 3.8 m (12 ft $5\frac{39}{64}$ in) tall when parked. The take-off weight was 2,340 kg (5,160 lb), which was just a little less than the RD-9BP's take-off thrust of 2,835 kgp (6,250 lbst).

On the whole the contraption looked like the least likely thing to fly. Yet fly it did. Predictably, controlling the Toorbolyot was not easy at all. The engineers at LII had to invent a special lift control device. Two petals controlled by the pilot were located below the edge of the engine nozzle at right angles to the engine axis. They were made of heat-resistant alloy and moved symmetrically in the horizontal plane to enter the exhaust jet, deflecting part of the efflux and thereby reducing lift; the engine ran at constant rpm all the while. This unusual device ensured sufficiently precise control in the vertical plane.

Above: LII test pilot Yuriy A. Garnayev, the project test pilot of the Toorbolyot, poses with his charge.

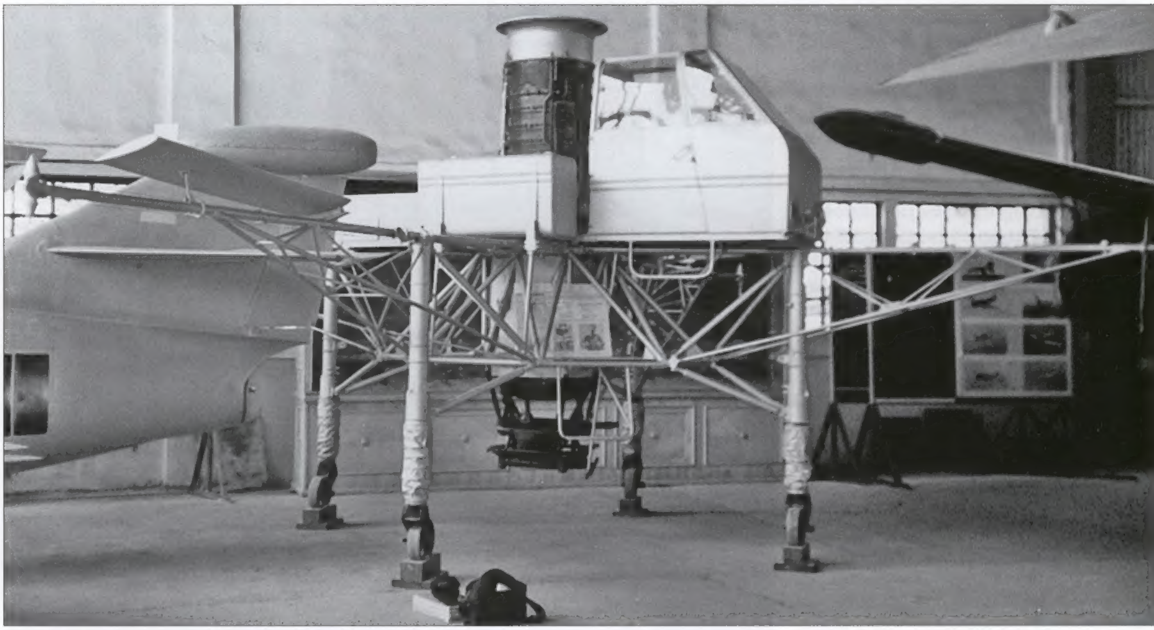
Garnayev made dozens of test flights in this unique aerial vehicle. He later recalled that the tests were mainly concerned with determining which type of controls – jet vanes or reaction control nozzles (puffers) – was best suited for controlling an aircraft in VTOL modes. The jet vanes were positioned in the engine efflux, so their efficiency depended on the engine's operating mode and thrust at the moment. The puffers, on the other hand, used compressed air bled from the engine. It turned out that a combination of both types provided the best results, allowing the VTOL aircraft to move in all directions while manoeuvring at low speeds.

The machine's stability and controllability were rather poor, requiring a steady hand and causing some concern on the part of the test crew; one false move could cause the Toorbolyot to flip over. Added to that, the flights were made at low altitude, which is why the pilot was not equipped with a parachute.

Little by little Garnayev mastered the unusual machine, concurrently preparing to demonstrate the Toorbolyot to the Soviet government and the public at the 1958 flying display at Moscow-Tushino airfield (such displays were held there annually). And the machine was certainly a sight to behold! Emitting an ear-splitting roar and belching a stream of hot exhaust, the strange contraption slowly rose from a cloud of dust and hovered above the ground; it tilted slowly here and there and did a full 360° turn around its vertical axis, as if waltzing in the air. Next, it tilted forward and moved towards the far end of the airfield, picking up speed. The journalists reporting on the event immediately dubbed the machine *letayushchiy stol* (flying table).

In good weather with no wind, the Toorbolyot was easy enough to fly. In a wind of up

Left: Garnayev stands beside the Toorbolyot, which still lacks the small forward windows.
Above: The team that created and tested the vehicle, including the designer Aram N. Rafaelyants (right).



The Toorbolyot has been preserved for posterity at the Soviet Air Force Museum (now Central Russian Air Force Museum) in Monino.

to 12 m/sec (24 kts) the take-off and landing procedure became somewhat complicated, as the vehicle drifted and there were no control surfaces with which to parry the drift. Yet the problem was solved by tilting the vehicle in the direction opposite to the drift. Garnayev's conclusion was that, providing the pilot was proficient enough, the Toorbolyot presented no great problems even in windy conditions. Usually the thing took off from and landed on a large sheet of metal, but on one occasion Garnayev managed to land the Toorbolyot successfully on an even grass surface at the abovementioned Tushino flying display.

The Toorbolyot featured an automatic flight control system – the first of its kind in the Soviet Union; however, in Garnayev's opinion, the system did little to improve the vehicle's control characteristics and could just as well be excluded. Apart from Garnayev, the machine was flown by other LII test pilots in 1957 – Fyodor I. Boortsev, Gheorgiy N. Zakharov and Sergey N. Anokhin. The report on the VTOL tests of this vehicle was endorsed in September 1957.

The tests of the Toorbolyot showed the need for automatic stabilisation systems to be used by VTOL aircraft in take-off, landing, hover and transition modes. They also allowed the designers to determine the required efficiency of the reaction control nozzles, verify the hovering altitude control system and find the optimum seat incline and control locations. The results of this research proved valuable when the Soviet Union's first true VTOL aircraft, the Yak-36, was being designed.

In 1959 the OKB-26 design bureau headed by Chief Designer Sorokin came up with the project of a Toorbolyot-like VTOL vehicle dubbed ***Zorkiy*** ('the keen-eyed one'). The vehicle was to be powered by an R-25-26 turbojet; no further details are available. (OKB = ***o****pytno-**kon**s**trook**torskoye **b**yu**ro*** – experimental design bureau; the number is a code allocated for security reasons.)

OKB-115 headed by the famous designer Aleksandr Sergeyevich Yakovlev achieved the greatest progress among the Soviet aircraft design bureaux in creating VTOL aircraft. Work in this direction at OKB-115 began in the late 1950s; this was made possible by the advent of the Tumanskiy R19-300, a compact and lightweight axial-flow turbojet rated at 900 kgp (1,980 lbst). In 1960 Yakovlev offered to develop a small and light VTOL aircraft provisionally designated Yak-104; it was to be powered by two modified R19-300s, each uprated to 1,600 kgp (3,530 lbst) and fitted with a vectoring nozzle, as lift/cruise engines plus a single standard R19-300 as a lift engine. With a 2,800-kg (6,170-lb) take-off weight and a 600-kg (1,320-lb) fuel load, the Yak-104 was expected to attain a top speed of 550 km/h (341 mph), a service ceiling of 10,000 m (32,810 ft) and a range of 500 km (310 miles); the endurance was to be 1 hour 10 minutes. The Yak-104 remained a 'paper aeroplane'.

Later, the production Yak-28 twin-turbojet tactical bomber evolved into a VTOL version designated Yak-28VV (*verti**kahl'**no vzle**ta**yushchiy* – VTO-capable). It had a similar layout, with two lift/cruise engines under the wings and a lift engine in the nose. The Yak-28VV, too, was not built.

In 1961 the Yakovlev OKB approached the State Committee for Aviation Hardware (GKAT – *Gosoo**dar**stvennyy komi**tet** po aviatsi**on**noy **tekh**nike*; that is, the former Ministry of Aircraft Industry) with three proposals concerning VTOL jets. These included a single-seat fighter-bomber powered by two Tumanskiy R21M-300 lift/cruise engines and an attack aircraft with two Tumanskiy R11V-300 turbojets coupled with lift fans buried in the wings; the fans were to be spun up by the turbojets' exhaust gases. At a glance, this layout offered a considerable weight saving as compared with alternative layouts; also, the thin fan assemblies of fairly large diameter seemed to be capable of providing the required lift. Yet, again neither project materialised.

(It has to be said that the buried lift fan concept seemed quite attractive in the late 1950s/early 1960s and was explored and discussed by the aviation experts of the world's major aircraft manufacturing nations. Even now the idea has not died completely; in the current version of the concept, however, the lift fans are to be driven mechanically off the lift-cruise engine, not by means of gas or air bleed.)

The course taken by VTOL aircraft development in the Soviet Union is the subject of this book.

Chapter 1

Yakovlev's *Freehand*

Yak-36 Experimental VTOL Strike Aircraft (*izdeliye* V)

In February 1961 GKAT submitted a report to the Council of Ministers (CofM) Presidium's Commission on defence industry matters (VPK – *Voyenno-promyshlennaya komissiya*). The report said, among other things:

'In order to ensure the required performance the engine must have a weight/thrust ratio of 0.08-0.1 kg/kgp [lb/lbst] versus 0.2-0.25 kg/kgp offered by current turbojet engines. Creating such a lightweight engine offering adequate performance is a highly complex task. In their attempts to achieve this goal OKB-300 (led by [Sergey K.] Tumanskiy) and OKB-165 (led by [Arkhip M.] Lyul'ka) and TsIAM have undertaken development [...] of a powerplant comprising a turbojet and a jet-driven lift fan, a short-life lift engine (turbojet) and a combined [lift/cruise] engine with a vectoring nozzle. [...] Proceeding from the results of this development work and considering the major technical problems associated with VTOL aircraft development and the complete lack of prior experience in this field, [...] A. S. Yakovlev and S. K. Tumanskiy have put forward the following proposal:

• At the initial stage of the programme an experimental single-seat fighter-bomber is to be developed for the purpose of evolving the piloting and operational (combat application) techniques. The aircraft is to be powered by two R21M-300 engines. This will be an upgraded version of the R21-300 offering higher thrust and having a lower structural weight; [...] The engine will feature a vectoring nozzle.

The ordnance load is to be 500 kg [1,100 lb]; the maximum speed at 1,000 m [3,280 ft] is to be 1,000-1,100 km/h [621-683 mph] and the range 500-600 km [310-372 miles]. The engines are to deliver a vertical thrust of 5,000 kgp [11,020 lbst] each, weighing 950 kg [2,090 lb] each.

The aircraft is to enter flight testing in the fourth quarter of 1963.

• In continuation of the VTOL aircraft programme a project of a heavier aircraft with more powerful engines is to be drafted. The new powerplant may be based on the R21M-300 turbojet which is to be mated with a lift fan assembly to provide a vertical thrust up to 10,000 kgp [22,045 lbst]. An aircraft powered by such engines can have a take-off weight up to 18,000 kg [39,680 lb].'

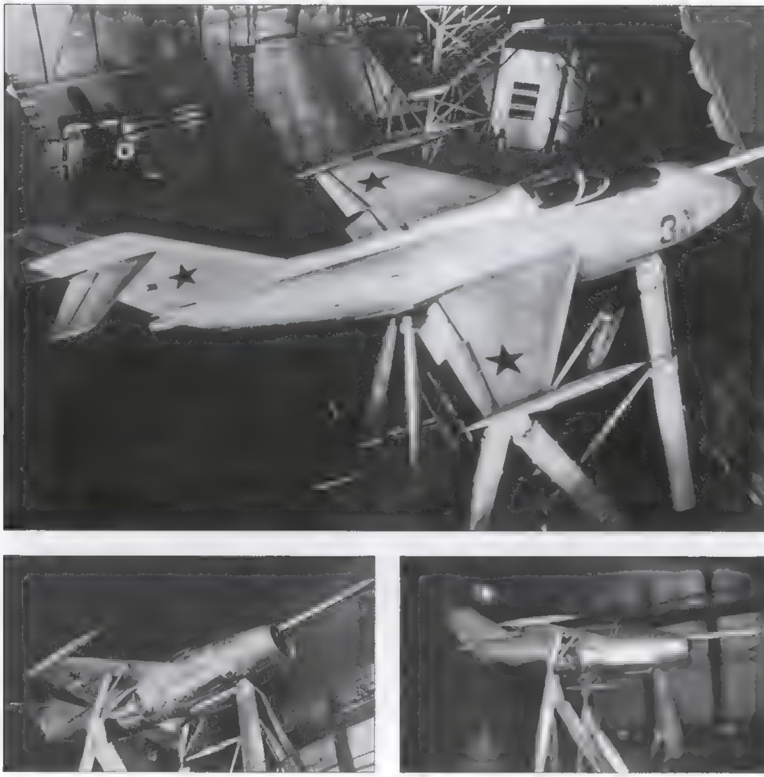
(Note: TsIAM is the Central Aero Engine Institute (*Tsentrahl'nyy institoot aviatsionnovo motorostroyeniya*). The R21-300 engine was not developed by the head office (OKB-300) but by the design office of aero engine plant No. 45 in Moscow; OKB-45 was headed by Nikolay G. Metskhvarishvili.)

On 30th October 1961 the Communist Party Central Committee and the Council of Ministers issued directive No. 947-418 tasking the Yakovlev OKB with developing and building a single-seat VTOL fighter-bomber powered by two 5,000-kgp R21M-300 engines. The aircraft, which received the provisional in-house designation Yak-V or *izdeliye* V, was designed for a maximum speed of 1,100-1,200 km/h (683-745 mph) at 1,000 m. The V referred to *vertikahl'nyy vzlyot i posahdka* – vertical take-off and landing; *izdeliye* (= product) such-and-such is a term often used for coding Soviet/Russian military hardware items in paperwork for security reasons. According to the stipulations of the directive, the aircraft's take-off weight was not to exceed 9,150 kg (20,170 lb). That same year TsIAM's branch office in the town of Turayevo commenced development of the Ts-22 test rig featuring an ejector-type wind tunnel; the rig was intended for testing the powerplants of various aircraft, including VTOL aircraft, in take-off and landing modes.

The Yak-V project, which was soon redesignated Yak-36, was initially the responsibility of OKB-115's preliminary design (PD) section under Leon M. Shekhter; Orest A. Sidorov was the aircraft's project chief. Choosing the general arrangement was no easy task; the problem was that in VTOL mode the thrust vector needed to pass through the aircraft's centre of gravity. To ensure this, ideally the engines should have multiple nozzles positioned fore and aft of the CG (as, say, on the Harrier's Rolls-Royce Pegasus turbofan); however, no such engine existed in the Soviet Union – even in project form. The only possible solution was to use a 'tadpole' arrangement similar to that used on the Yakovlev OKB's first jet fighters (the Yak-15, Yak-17 and Yak-23) – that is, the engines were to be mounted side by side in the forward fuselage so that the nozzles would be located at the aircraft's CG. The engines featured special revolving nozzles allowing the thrust vector to be changed smoothly from vertical to horizontal (for forward flight) and back again. The task of designing the powerplant layout, including the vectoring nozzles, and the reaction control system with puffer nozzles in the aircraft's nose, tail and wingtips was entrusted to Stanislav G. Mordovin.

Instead of the R21-300s intended originally the OKB designed the Yak-36 around a

A desktop model of the Yak-36 (*izdeliye* V) VTOL attack aircraft, showing the long outrigger boom of the forward reaction control nozzle. Note the cannon pods under the wings.



Above: Three views of the first Yak-36, '36 Yellow' (the ground test example), in the T-101 wind tunnel at TsAGI. Before that, the machine had already made tethered hovers. Note the sharply tapered wings.

pair of Tumanskiy R27-300 two-spool axial-flow turbojets. The latter engine, which was a derivative of the R21-300, had been developed for the MiG-23 advanced tactical fighter. It had a take-off rating of 5,300 kgp (11,680 lbst) and a dry weight of 950 kg (2,090 lb), which equalled a weight/thrust ratio of 0.179 – a bit short of the desired figure.

After considering several alternative layouts the designers settled for a conventional mid-wing layout. The all-metal airframe featured a semi-monocoque fuselage of low fineness ratio and trapezoidal wings of single-spar construction with slight anhedral, a low aspect ratio (2.7) and 40° leading-edge sweep. The wings had no leading-edge devices, the trailing edge being occupied by one-piece flaps and ailerons. The moderately swept tail surfaces had a cruciform layout, as on the Yak-25/Yak-27/Yak-28 family of tactical aircraft. The landing gear design was likewise borrowed from Yakovlev's tactical twinjet family – the Yak-36 had a bicycle landing gear with a forward-retracting single-wheel nose unit and an aft-retracting twin-wheel main unit; the outrigger struts retracted forward into cigar-shaped wingtip fairings, as on the Yak-25RV high-altitude reconnaissance aircraft. The choice of the bicycle gear was dictated by the powerplant arrangement – the engines and their vectoring nozzles left no room for a tricycle landing gear's mainwheel wells. The starboard wingtip fairing carried a standardised air data boom with pitch and yaw transducer vanes.

The engines breathed through a large elliptical air intake at the forward extremity of the fuselage which was divided into two inlet ducts by a vertical splitter; the latter accommodated the nosewheel well and incorporated a landing/taxi light. The engine nozzles were mounted on spherical joints, rotating through more than 90° in the vertical plane for thrust vectoring. The port and starboard nozzles were linked by a synchronisation shaft to preclude asymmetrical deflection and hence thrust asymmetry. A water/methanol mixture was injected at the compressor faces to boost the engine thrust in vertical take-off mode.

To ensure control in the hover and during transition to and from forward flight the Yak-36 featured a reaction control system with puffers to which engine bleed air was sup-

A rare colour photo of Yak-36 '36 Yellow'; note that the areas where the reaction control nozzles are located were painted yellow, making the nose boom look like a monstrous sulphur-tipped matchstick. The quality of the Soviet colour film, which was poor to begin with, has deteriorated after all these years.

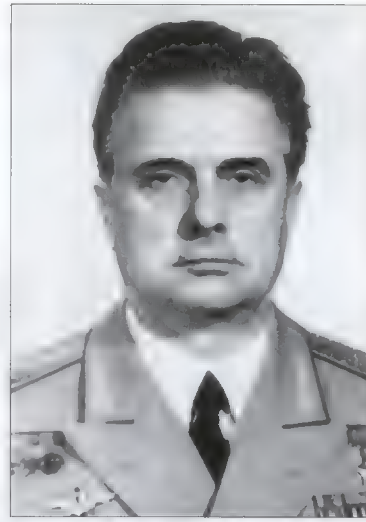
Above: This view of '36 Yellow' in its early guise shows the original small elliptical air intake (with a landing light built into the splitter), the one-piece door of the main gear unit and the absence of recirculation dams. The fixtures under the wings, where the weapons pylons ought to be, served for attaching the tethers.

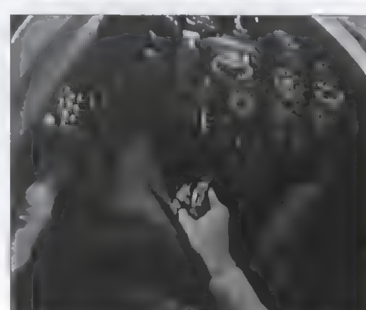
A three-quarters rear view of the same machine, showing the large vectoring nozzles in the forward thrust position and the lack of ventral fins. The nosewheel and the mainwheels were of identical size.

Left: Yuriy A. Garnayev was actively involved in the tests of the Yak-36 as well. Here he is seen with the Gold Star Order that went with his Hero of the Soviet Union title.

Right: Valentin G. Mookhin, who bore the brunt of the Yak-36's flight tests, is shown here in his Major General's uniform with the Gold Star Order (he received the HSU titles for testing the Yak-36).

Below right and bottom right: Mookhin takes a round on the Yak-36's flight simulator which was used to assess the control characteristics before attempting a real flight.





plied. In order to create the required moment arm the forward reaction control nozzle was located at the tip of a long thick boom extending far forward from the air intake's upper lip; the other three puffers were placed in the wingtip pods and under the tailcone. For pitch and roll control, the puffers were controlled either by a duplicated two-channel autopilot or manually by means of the stick; for directional control, they were controlled manually by means of the rudder pedals. The amount of bleed air for the reaction control system could reach 10% of the engines' mass flow; the air bleed was to be disabled automatically as the aircraft accelerated to an indicated airspeed of 400 km/h (248 mph).

The Yak-36 featured a special crew rescue system designated SKE (*sistema katapool'teerovaniya ekstrennaya*) that was designed to ensure safe ejection in all flight modes, including vertical flight, hover and transition to and from forward flight. Not sure how their brainchild would behave in the vertical and transitional flight modes (after all, the Yak-36 could be expected to tip over after lifting off or do some other dirty trick), the designers incorporated a unique safety feature. For the first time in world aircraft design practice, the crew rescue system automatically recognised a critical situation by monitoring the pitch and roll rates. Should these rates exceed a certain limit, the system automatically restrained the pilot's arms and legs, yanking his hands off the throttle and stick, and ejected him through the cockpit canopy, whether he wanted it or not. The entire process was a omplished in just 0.4 seconds. This er ced ejection procedure was adopted be se on a VTOL aircraft, as distinct from onventional aircraft, the pilot might n ave sufficient time to assess an emerg y situation correctly and take action; by the time he initiated ejection manually it would quite probably be too late.

During a vertical take-off the automatic ejection system was activated manually at an altitude of 5 m (16 ft and disabled when the engine nozzles rotated past 45° from the vertical. During the landing approach the system was again activated manually as the aircraft decelerated and the nozzles were rotated into the vertical position; it was switched off when the aircraft was down to 5 m. OKB-115 built a special swivelling test rig for the purpose of verifying the SKE ejection system.

In addition, the Yak-36 had an automatic control system stabilising the aircraft at forward speeds close to zero.

Though basically a technology demonstrator, *izdeliye* V had two wing hardpoints for carrying various weapons. Possible options were two R-3S infrared-homing air-to-air missiles, two bombs of up to 250 kg (551 lb) calibre, two UB-16-57 or UB-32 rocket pods holding sixteen or thirty-two 57-mm (2.24-in) S-5 folding-fin aircraft rockets apiece, two air-to-air missiles or two UPK-23-250 pods, each containing a 23-mm (.90 calibre) Gryazev/Shipunov GSh-23 cannon with 250 rounds. The latter pod was developed by the Yakovlev OKB specially for the Yak-36 but subsequently found use on many Soviet tactical aircraft. (Note: UB = *oonifitseerovannyy blok* – standardised [FFAR] pod; UPK = *oonifitseerovannyy pushechnyy konteyner* – standardised gun pod).

The unique design features incorporated in the Yak-36 required large-scale and lengthy theoretical research and model tests. Therefore the development of the first Soviet VTOL aircraft was thus organised that model tests (such as wind tunnel tests) and verification of systems and components on test rigs proceeded virtually in parallel with the design process.

Four examples of the Yak-36 were laid down at the Yakovlev OKB's prototype construction facility, MMZ No. 115 *Skorost'* (*Moskovskiy mashinostroitel'nyy zavod* – Moscow Machinery Plant No. 115 'Speed'). Wearing the very appropriate tactical code '36 Yellow', the first example was a ground test article intended for exploring the thermal and

gas dynamic patterns arising during vertical take-off and landing. This was to take place during tethered tests. The second example was a static test airframe, while the third and fourth aircraft were the first and second flying prototypes.

The ground test article was completed in the autumn of 1962 and delivered to the OKB's flight test facility in Zhukovskiy for tethered tests. During the tests the aircraft was suspended from a so-called cable crane; the latter consisted of two truss-type metal towers whose tops were connected by horizontal cables. A vertical cable hung from the middle of these cables; the aircraft was attached to it via a mechanical or tension-type dynamometer which indicated the actual lift. To prevent an unintentional take-off the aircraft was attached to the ground by more cables allowing it to lift off just a little.

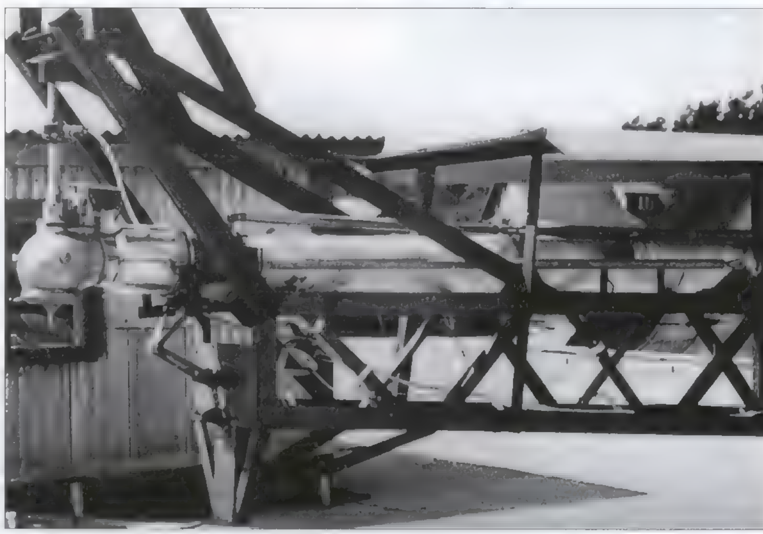
LII test pilot Yuriy A. Garnayev was appointed the Yak-36's first project test pilot; apart from the Toorbolyot, he had gained considerable experience flying various types of helicopters. Valentin G. Mookhin, a Yakovlev OKB test pilot, was selected as his back-up (he would be a stand-in if Garnayev could not fly a test mission for any reason). Arkadiy P. Bogorodskiy was the check-up test pilot; O. A. Sidorov and V. N. Pavlov were the engineers in charge of the tests, while Dmitriy A. Kolotoorskiy and V. K. Kuz'min were assigned to the prototypes as mechanics.

The subject of pilot training was taken seriously, and a lot was done in this area before the flight tests could begin. The Yakovlev OKB created a special flight simulator featuring a cockpit and special display; this served for coaching the pilots in the techniques of vertical climb/descent, hovering at altitudes up to 5 m and low-speed manoeuvring above an imaginary landing pad whose limits were indicated on the display. The technique used was quite similar to flying a helicopter: the altitude was adjusted by advancing or retarding the throttles (in similar manner to the use of a helicopter's collective pitch lever), while forward, reverse and sideways motion was accomplished by gently moving the stick (like a helicopter's cyclic pitch lever). Additionally, the pilots assigned to the Yak-36 programme made a series of training flights in a Mil' Mi-4 transport helicopter, practising vertical climb/descent, low-altitude hover and acceleration/deceleration over the runway at Zhukovskiy.

The tethering cables attached to Yak-36 '36 Yellow' were long enough to allow the aircraft to rise 5 m (16 ft) above the ground, which was sufficient for the first stage of the tests. However, the aircraft suffered an engine surge the very first time it attempted to lift off. It turned out that, relying on their experience with conventional take-off and landing (CTOL) jets, the designers had made a mistake, assuming it would be sufficient to place the engines so that the thrust vector passed through the aircraft's CG. The designers believed that all they needed was to point this vector in the right direction for vertical take-off or hover and for level (forward) flight. However, as mentioned in the introduction, the very first experiments with vertically mounted jet engines and the subsequent flights of the Toorbolyot showed that the exhaust jet fanned out in all directions along the ground instead of bouncing off it. The jet efflux gradually cooled down and decelerated as it mixed with the ambient air and came into contact with the runway surface. Then, at a distance equal to several dozen times the engine nozzle diameter the jet efflux parted company with the runway surface, forming a billowing cloud which could be ingested by the engines. This was fraught with danger, as exhaust gas ingestion did not occur uniformly and sharply disrupted the airflow at the engine compressor face, causing a compressor stall and leading to sharp pressure fluctuations inside the engine (engine surge). At best this resulted in a flameout; at worst, major structural damage to the engine could occur. And the loss of thrust in vertical flight mode was bound to be fatal for the aircraft.

The Yak-36 showed a proclivity to engine surge almost immediately. Half of the exhaust

Above: The so-called 'cable crane' dynamometric rig used for tethered hovering tests. The aircraft was hooked up to the bar suspended from the transverse cables.



This test rig served for checking out the Yak-36's reaction control system. One of the lateral puffers and its air supply duct are shown here.

This test rig served for verifying the Yak-36's fuel system. A Yak-40 feederliner, CCCP-87687, is parked beyond.

The crew rescue system test rig built under the programme is shown just as a Yakovlev KYa-1 ejection seat with a dummy is catapulted from it. The rig could be tilted to emulate various attitudes of the aircraft.

gases impacting the ground flowed harmlessly to the rear, but the other half flowed forward, and much of it was ingested by the engines straight away. The temperature field at the inlets became critically irregular, and the engines started 'hiccoughing'.

Another major problem that surfaced at this stage was runway erosion. The problem was especially acute for concrete runways and hardstands on which the high-speed hot exhaust jets flowing vertically from the deflected nozzles took a heavy toll. The concrete would start cracking and crumbling, the fragments flying in all directions; quite apart from the runway itself, this created a real danger of foreign object damage (FOD) to the engines. The designers concluded that the best solution was to provide the locations from which VTOL aircraft were to operate with special jet blast deflectors – trenches faced with concrete and covered with heavy-duty steel grilles. Such a deflector was constructed at Zhukovskiy by the early summer of 1963, and when the Yak-36 was parked over it the engine surge problem was temporarily resolved. However, building such deflectors was a complex affair (and often it would be simply impossible), and the idea was dismissed as impracticable.

The aircraft, too, had to be modified by eliminating the twin spring-loaded blow-in doors on the forward fuselage side immediately ahead of the nose gear fulcrum. This measure proved insufficient – but more of this later.

On 9th January 1963 Yak-36 '36 Yellow' made its first tethered hover with Yuriy A. Garnayev at the controls. Not yet a true flight, but at least the thing was willing to fly.

Or was it? Tests revealed other unpleasant phenomena. In particular, with the engine nozzles being located close to the aircraft's CG, the jet efflux spreading out in all directions created a partial vacuum under the aircraft – a suction effect reducing the lift considerably. According to the designers' estimates, this suction force was not to exceed 450-500 kg (990-1,100 lb). In reality it turned out to be much stronger; moreover, it varied, depending on the wind speed and the aircraft's attitude along the longitudinal and transverse axes. Theoretically, an available engine thrust only slightly greater than the aircraft's take-off weight should allow a VTOL aircraft to soar; in reality a thrust/weight ratio of at least 1.1 or 1.12 was needed.

The Central Aerodynamics & Hydrodynamics Institute named after Nikolay Ye. Zhukovskiy (TsAGI – *Tsen**trahl**'nyy **a**ero- i **ghid**rodina**mich**eskiy institoot*), which at that time was headed by the outstanding aircraft designer Vladimir M. Myasishchev, undertook large-scale research on the interaction between a VTOL aircraft's lifting surfaces (wings and horizontal tail) and the jet efflux in vertical thrust mode. The work was undertaken by the institute's VTOL aircraft section (headed by Boris N. Frolishchev) with the participation of V. A. Golubov, I. V. Krasnov, V. G. Kool'tin, S. D. Sytnik and other specialists. The VTOL aircraft section designed and built the VV-1 test rig which was used for extensive tests with a number of scale models of the Yak-36. These tests revealed significant thrust losses (the aforementioned suction effect) caused by the interaction of the exhaust jets with the wings and tail surfaces in VTOL modes.

TsAGI also undertook other research associated with the Yak-36 programme. Among other things, in 1963-64 the ground test article ('36 Yellow') was tested in TsAGI's T-101 wind tunnel, which is large enough to take full-size fighters; the aircraft had by then completed its test cycle on the cable crane. After analysing the wind tunnel tests

Frolishchev and Aleksandr G. Kookinov developed a whole set of measures aimed at ensuring flight safety in VTOL, hover and transitional flight modes. TsAGI specialists also did a lot of work to give the Yak-36 adequate stability and handling. Analysis of the reaction control system's required efficiency, which was undertaken on the flight simulator by Gleb V. Aleksandrov and A. N. Predtechenskiy, corroborated the results obtained earlier with the Toorbolyot.

It took a lot of effort to bring the Yak-36's control system up to scratch. At the suggestion of Gleb V. Aleksandrov (TsAGI) and Grigoriy S. Kalachov (LII) the Yakovlev OKB decided to build the SSM dynamometric test rig (*stend sil i momentov* – force and moment [measuring] rig). This rig proved valuable for designing and testing the control systems of all subsequent Yakovlev V/STOL jets.

Coded '37 Yellow', the first flying prototype of the Yak-36 (the third example built) arrived at the flight test facility in the spring of 1963. Once ground checks of all systems had been completed, this aircraft, too, began a series of tethered tests on the cable crane, superseding the non-flyable first example. In June and July 1963 Yuriy A. Garnayev made the first hovers in '37 Yellow', lifting the machine initially just 0.5 m (1 ft 7 in) above the jet blast deflector's grille. On 23rd June the Yak-36 made its first free (untethered) hover; this was the beginning of a series of free hovers in which the aircraft reached altitudes up to 5 m above the ground. (It may as well be said now that a total of 85 tethered hovers was made during the first two years of the Yak-36's test programme.)

For the time being the Yak-36 was not ready for a 'real' vertical take-off, the OKB being busy solving the problems associated with the structural design and the control system. Meanwhile, GKAT demanded that a short rolling take-off be made.

Viktor N. Pavlov, the engineer in charge of the flight tests, recalls that the specialists then had only the faintest idea of the Yak-36's control characteristics and were not sure how the aircraft would behave, but they had orders to obey. He recalled that the aircraft's first real take-off was more like a circus act. The aircraft (piloted by Garnayev) rolled along the runway, while a mobile control tower mounted on a lorry (with Pavlov inside) followed it along the runway verge. Having started and warmed up the engines, Garnayev requested permission to take off and was cleared to do so. After a take-off run of some 50-60 m (164-200 ft) the machine became airborne, literally leaping 10-15 m (33-50 ft) into the air, and flew on, wobbling crazily around all three axes as it did. It was a pretty scary performance.

Top and above: Yak-36 '36 Yellow' suspended from the 'cable crane'. The latter was quite a large installation, as this view shows!

Here, '36 Yellow' becomes airborne and tugs at the tethers during early ground tests. Note the twin auxiliary intake doors on the sides of the nose. The aircraft is parked over a special exhaust gas evacuation device – a specially shaped pit closed by a steel grille.

Above: A close-up of the Yak-36's port vectoring nozzle in forward thrust position and the port wingtip reaction control puffer.

Above: '37 Yellow', the first flying prototype, shows off some of the modifications made in the course of the tests – the enlarged oval air intake, the hinged recirculation dams and the longitudinal strakes.

'The pilot was supposed to lift off, tightening the cables by which the aircraft was tethered to the [jet blast deflector] grille, then throttle back a bit so that the aircraft would descend a little, slackening the cables, and try a free hover,' – Pavlov reminisced. – *'The mission was to keep the aircraft in this position and try to control it. Even now, when forty years have passed, I shudder inside when I recall this 'circus act'. I believe that everyone who was watching those acrobatics held their breath until the aircraft was safely back on the ground. The thing is, it is easy enough to tighten the tethers – you rev up the engines, the aircraft lifts off, the cables go taut and there's nothing more left to do for the pilot. The real 'fun' began when the pilot tried to descend half a metre; as he did, the aircraft would try to stray to one side for some reason and would be restrained by the tether on the other side, the pilot trying to control the machine all the while. In short, the result was no good.*

'[...] I believe that Garnayev, with his composure and all his huge experience, was the only one who could have succeeded in landing the machine on the runway, throttling back gently and working the stick in a circular motion (to counter the aircraft's spontaneous bucking – *Auth.*). *The aircraft ran off the runway after touchdown and came to a standstill on the grass. When we drove up a few seconds later, Garnayev had already left the cockpit and was standing beside the aircraft. He was pale. "That way you could end up with a wrecked aircraft" – he told us, almost tranquilly.'*

The efforts to create the first indigenous VTOL aircraft evoked keen interest on the part the Soviet Ministry of Defence's top brass.

This three-quarters view of the same aircraft shows the splayed ventral fins improving directional stability, with a 'towel rail' data link aerial between them, and the double-action main gear door. The pictures were taken at Moscow-Domodedovo during the rehearsal of the flying display for the 9th July 1967 airshow.

Above: '37 Yellow' lifts off vertically at Domodedovo with the recirculation dams deployed.

Right and below right: The first flying prototype transitions to forward flight; the recirculation dams are already up and the gear begins to retract.

In July 1963 Marshal Rodion Ya. Malinovskiy, the then Minister of Defence, paid a visit to LII together with a group of generals to watch the Yak-36 making a tethered hover. This is how Viktor N. Pavlov recalls the episode:

'Garnayev opened up the throttles and the aircraft rose smoothly to an altitude of some 5 m, tightening all four tethering cables; it hovered up there for about five minutes, tugging at the tethers, whereupon it descended just as smoothly and touched down. This was a sight to behold. The visitors were absolutely elated and departed without making any critical comments.'

In parting, Malinovskiy thanked the creators of the aircraft, praising their work. Still, although the top brass were impressed, the Yak-36 was in trouble: the designers had run into a whole spate of major technical problems, and resolving them took a lot of time and a maximum of effort.

The very next day after Malinovskiy's visit the port engine surged while the Yak-36 was hovering. Losing altitude rapidly, the machine slammed down onto the jet blast deflector grille and the port outrigger strut collapsed. The damaged unit was quickly replaced, but the message was clear; such a surge-prone aircraft was unsafe to fly, to say nothing of the jet blast deflector pits which would be costly to build and impractical.

The designers set to work, trying to cure the malaise – or at least the most acute symptoms. General Designer Aleksandr S. Yakovlev appointed Stanislav G. Mordovin as his deputy with overall responsibility for the Yak-36 programme and tasked him with developing radical solutions that would cure

Above: '37 Yellow' makes a banked turn during its demo flight at Domodedovo. The tubby Yak-36 was a singularly ungainly aircraft.

Above: The Yak-36 has landed on a platform barely exceeding the aircraft's dimensions, showing its ability to operate in extremely confined spaces.

the surge problem once and for all. At Mordovin's suggestion, the OKB built a very basic model emulating the Yak-36's vectoring nozzles. Using this model, OKB engineers S. A. Strakhov and R. V. Kogaut explored the exhaust gas distribution patterns; this research made it possible to issue preliminary recommendations on how to prevent exhaust gas recirculation.

Meanwhile, LII was evolving measures to protect the Yak-36 and its powerplant against the hot exhaust gases, using a purpose-built powerplant test rig – the so-called Rig D. This was a heavy-duty metal frame resting on a wheel undercarriage and mounting two Tumanskiy R11F-300 turbojets (the model used on the MiG-21F fighter and some other types of tactical aircraft). The R11F-300 was fairly close to the R27-300 as far as thrust, mass flow and other basic performance parameters were concerned. Unlike the real aircraft, Rig D did not have vectoring nozzles, which were substituted by fixed nozzles angled vertically downward. The relative positions of the engine intakes, inlet ducts and nozzles, the nozzles' ground clearance and the placement of the reaction control system puffers exactly replicated the actual aircraft. The engines were remotely controlled from a cabin located about 20 m (65 ft) away; the cabin featured an instrument panel with a full set of gauges for monitoring the engines' rpm, turbine temperature, fuel and oil pressure and so on. Rig D rested on a concrete pad faced with steel sheets. V. P. Vlasov (Yakovlev OKB), L. I. Vernyy (LII) and K. K. Lavrent'yev (Tumanskiy OKB) were all appointed project engineers for the test rig by their respective enterprises.

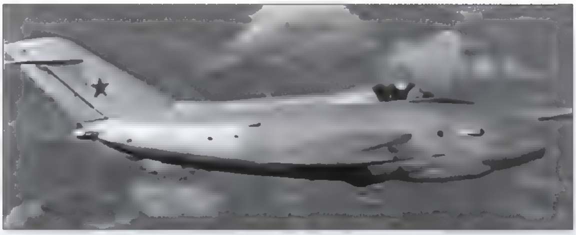
Rig D actually showed a propensity to engine surge caused by exhaust gas recirculation even before the problem surfaced on the actual aircraft. Experiments undertaken with the rig gave valuable results, helping the engineers to understand the cause of the problem and develop countermeasures.

Gradually the first prototype Yak-36 started performing taxi runs and hovers at low altitude. Later, in the midst of the test programme, Yuriy A. Garnayev (who, as already mentioned, was an experienced helicopter pilot) was dispatched to France to assist the French in fighting forest fires; Valentin G. Mookhin continued the tests in his absence. Tragically, Garnayev was killed when his Mil' Mi-6PZh fire-fighting helicopter (CCCP-06174) crashed near Marseilles on 7th August 1967;

The second flying prototype Yak-36, '38 Yellow', as originally completed with the small elliptical air intake, auxiliary blow-in doors and no recirculation dams or ventral strakes or fins. Note the wing pylons.

Excellent colour views of the second flying prototype prior to modification. The reaction control puffers are marked by yellow boxes and the data link aerial under the tail is well visible. Note how the machine sits 'on an even keel', neither of the outrigger wheels touching the ground.

Above and below: The same aircraft in modified form with the enlarged air intake and the forward recirculation dam deployed – the machine appears to be rudely sticking out its tongue. The intake splitter features no landing light and the pylons are removed. Note that both outrigger wheels rest on the ground in this case.

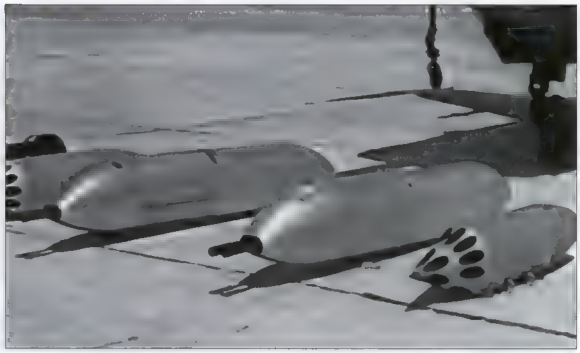


Top: The as-yet unmodified Yak-36 '38 Yellow' in flight; the sharply tapered nose is visible.

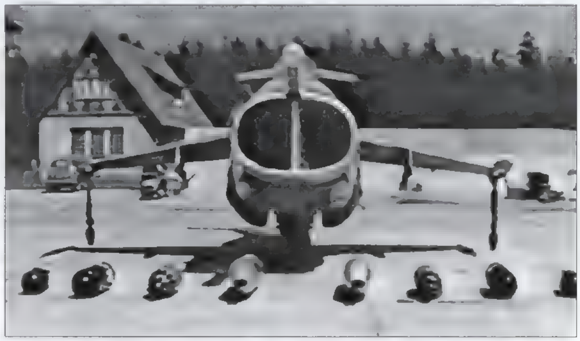
Above: Yuriy Garnayev greets the designers and ground crew after a test flight in the modified machine.

Right: Garnayev poses for a photo with the second prototype. The forward recirculation dam formed small lateral strakes when retracted.

Below: Another aspect of '38 Yellow' in later configuration with ventral fins, revised main gear doors and both recirculation dams open.



Above, left and below: The second prototype is seen here parked at the Yakovlev OKB's flight test facility in Zhukovskiy with R-3S missiles on the wing pylons and a weapons array in front (UPK-23-250 cannon pods, UB-16-57UM FFAR pods, FAB-100 and FAB-250 bombs) for the benefit of an MoD delegation. Note the quaint-looking cottage in the background with a jet blast deflector wall beside it. The engine nozzles are in vertical thrust position.



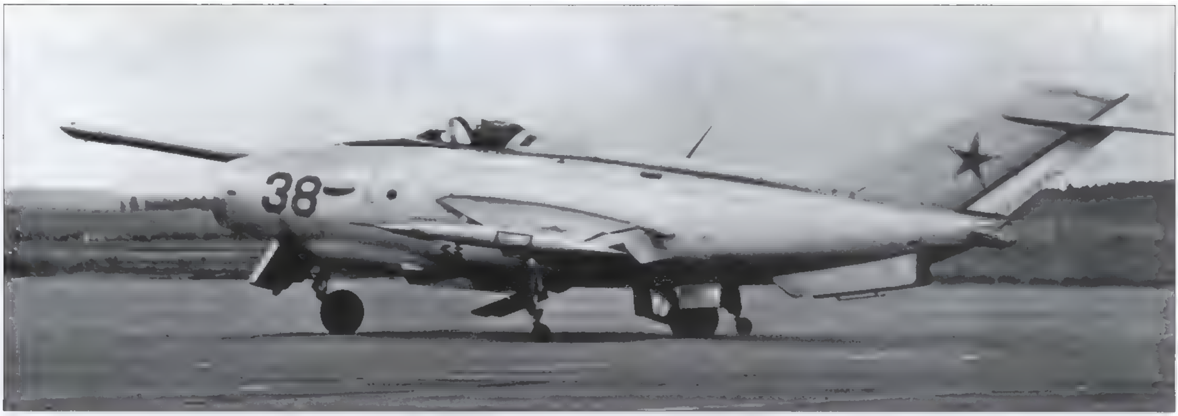
Above and right: Two more views of the Yak-36 and its advertised weapons at Zhukovskiy, with Yak-30 jet trainers, a Yak-28 bomber and a Yak-12 utility aircraft parked in the background. The MoD officials were happy with what they saw.

Mookhin now became the Yak-36's project test pilot and had to shoulder the main test workload.

On 23rd July 1963, exactly a month after Garnayev's first brief flight in the Yak-36 recounted by Pavlov, Mookhin performed the same mission profile (a vertical take-off and a brief hover at low altitude followed by a vertical landing) three times in one day. On 24th and 30th July he made six more hovers.

After Mookhin had successfully made the first few hovers, the test team asked Garnayev to attend the tests; Garnayev was to sit in the command radio van and advise Mookhin of the hovering altitude over the radio. Having performed a five-minute flight and received no altitude information whatever, the pilot reproached his colleague: 'How come you didn't give me any altitude figures?' Garnayev replied, his eyes burning with excitement, 'I had forgotten all about it! It was such a magnificent sight!'

Mastering vertical landings was the hardest bit; the test pilots were at odds over the



Above: Here, the second flying prototype is armed with two UB-16-57UM rocket pods. The Yak-36 had a strong nose-up ground angle.

issue of which technique was best. Garnayev insisted that a helicopter-like descent from a considerable altitude should be used, the pilot having killed the forward speed in advance. Mookhin, however, had different ideas; he was aware that, unlike a helicopter, which relied entirely on its rotor(s) to provide lift, on a VTOL aircraft the lift was provided by the wings or by the engine exhaust (or both), depending on the flight mode. The transition from wing lift to jet lift depended on the forward speed; therefore, Mookhin argued that the landing approach should be initiated at the airfield's traffic pattern altitude. Subsequent events showed that Mookhin was right. He reminisced:

'In the hover, the aircraft's altitude above the ground was controlled by the throttles and its attitude with respect to the CG by the reaction control nozzles. Additionally, the aircraft featured two demi-sets (sic – *Auth.*) *of the autopilot which provided so-called artificial damping* (of oscillations – *Auth.*). *In the pitch control channel the autopilots also maintained the required angle of attack. Whereas the aircraft's pitch and yaw control were good enough, the roll control efficiency was inadequate. More than once after lifting the aircraft 0.5-0.7 m [1 ft 7 in to 2 ft 3 in] off the ground I was compelled to land immediately because the aircraft would bank, even full deflection of the stick was insufficient to counter this. They tried to persuade me, saying that the ground effect was to blame for this and roll control would get better if I climbed a little higher… Yet, some sort of intuition told me it would not.'*

Mookhin had some heated arguments with the designers. As Viktor N. Pavlov recalls, when one of the engineers tried to persuade the pilot to take the machine up to an altitude of 5 m (16 ft) Mookhin shot back, 'Go ahead, try it yourself'.

Later, test pilot Arkadiy P. Bogorodskiy was tasked with flying the Yak-36 in order to give the designers an unbiased view of the problems they were facing. Bogorodskiy managed to lift the aircraft approximately 1 m (3 ft 3 in) off the ground, whereupon the Yak-36 tipped over and landed roughly, damaging a wingtip and an outrigger strut. That did it; the designers admitted that the roll control channel needed modifications.

Above and below: Yak-36 '38 Yellow' takes off vertically at the Domodedovo airshow, belching smoke. Note the absence of the blow-in doors which were eliminated when the main intake was enlarged.

Above and left: Further aspects of the second prototype. Note the longitudinal strakes under the centre fuselage flanking the rear recirculation dam.

Below: The same aircraft in airshow configuration. The FFAR pods were painted Dayglo orange for higher conspicuity.

Right: This sequence of stills shows the Yak-36 beginning its demonstration flight with a vertical climb and then making a high-speed flyby.

Far right, above and centre: More views of '38 Yellow' as it taxies and takes off with the airport buildings in the background.

Far right, below: Valentin G. Mookhin flew the Yak-36 at the Domodedovo airshow.


38

Left: The Yak-36 'cleans up' as it passes overhead; the outriggers retract first. Above: This view illustrates the shape of the Yak-36's fuselage which is bulged amidships and tapers off sharply towards the tail.

The attempts to cure the aircraft's control system and, equally importantly, resolve the exhaust gas recirculation problem dragged on for a year, continuing from mid-1963 to mid-1964. General Designer Aleksandr S. Yakovlev was known as a cautious man, and this attitude spread to all of the OKB personnel involved in the VTOL programme. Little by little the designers expanded their experience with the VTOL aircraft, undertaking one experiment after another; yet, as Yakovlev himself put it, 'each of our successes in this field posed more problems than it solved'.

At first, trying to minimise the required air bleed and the thrust losses arising from it, the designers decided to slave the engines' fuel pumps to the control stick so that lateral motion of the stick would cause differential thrust, assisting roll control (after all, the engine nozzles were located on both sides of the CG). Yet, resonance frequency tests of the aircraft's control system shattered the designers' hopes. It turned out that the reaction control nozzles at the wingtips responded immediately to stick inputs but the engines responded with a considerable delay due to the operating algorithm of the fuel controls, and this delay negated any advantage caused by the differential thrust, which simply came too late. The designers had to seek a different solution; the only options were to increase the air bleed, thus improving the reaction control system's efficiency but caus-

This view shows details of the second flying prototype's underside; note the fixed strakes flanking the rear recirculation dam, which has its own strakes.

ing an even greater thrust loss, or to increase the engines' turbine temperature and hence the thrust (allowing more air to be bled without incurring unacceptable losses – *Auth.*). This required additional bench tests of the modified engine; also, the air supply ducts leading to the wingtip reaction control nozzles had to be redesigned.

In order to save time the designers decided to increase the wingtip puffers' moment arm by moving them outboard 1 m. Additionally, retractable recirculation dams with lateral strakes were installed under the nose and the centre fuselage, and an air curtain system preventing recirculation (with vertical compressed air jets trapping the wayward exhaust gases) was fitted for good measure. Eventually these efforts bore fruit – the engines ran stably at last. To be on the safe side, the efficacy of the modifications was initially tested in tethered flight on the cable crane, the aircraft hovering at up to 5 m (16 ft).

The second flying prototype Yak-36 (the fourth and final example) was coded '38 Yellow'. Initially it served for verifying the modified reaction control system, the autopilot and the rearranged controls in the cockpit. Eventually the designers established the proper air bleed rate that made the machine stable in the hover and responsive to control inputs.

On 27th July 1964 Valentin G. Mookhin took the second prototype up on its maiden flight involving a conventional short take-off and a conventional landing. After this, all three flyable examples, including the ground test article ('36 Yellow'), were modified to feature an enlarged engine air intake whose shape was changed from elliptical to oval. In so doing the landing/taxi light was moved from the air intake splitter to the port side of the forward fuselage and made retractable. At the same time two splayed trapezoidal ventral fins were added to the rear fuselage. The modifications produced the desired result – the aircraft was now stable at all altitudes and handled well.

The Yak-36's test programme was extremely intensive. For example, in the course of 20 days (between 4th and 24th September 1964) the aircraft made 27 hovers! Finally, on 29th September, two months after the second prototype's maiden flight, Mookhin made the first three free hovers in '38 Yellow'; sixteen more free hovers followed between 1st and 31st October. On some occasions Mookhin would even let go of the stick, and the Yak-36 remained rock steady. Still, perfecting this flight mode was a complex and time-consuming task.

After every single flight or hover Yakovlev OKB engineers Stanislav G. Mordovin, Kerim B. Bekirbayev, Viktor N. Pavlov, Yakov M. Galinskiy and V. I. Baranov, together with LII's aerodynamicists Anatoliy I. Kvashnin and G. M. Lapshin, would carefully analyse the flight data recorder readouts. Only when this had been completed would the go-ahead be given for the next flight.

People who witnessed the tests of the Yak-36 testify that the pilot's comments about the aircraft grew more and more favourable as time passed and the design was steadily improved; Mookhin even said that the Yak-36 was easier to fly than a conventional aircraft. Nevertheless, it took almost 18 months of hard work and training to make another milestone possible; on 7th February 1966 the Yak-38 took off vertically, made a circuit of the airfield and performed a conventional landing. In the 15 missions involving level flight at this stage, the Yak-36's flight envelope was explored and the required corrections to the pitot tube readings were determined.

All in all, between 29th September 1964 and 24th March 1966 the Yak-36 prototypes made 122 free hovers, vertical take-offs, vertical landings and low-speed manoeuvres. On 24th March 1966 Valentin G. Mookhin performed the first complete VTOL flight profile – that is, a vertical take-off followed by a transition to level flight and then a vertical landing.

The test programme was broken down into six stages – ground tests, tethered hovers, free hovers, CTOL flights, VTOL flights involving transition to and from level flight and, finally, live weapons tests. The latter calls for some explanation. Originally the Yak-36 had no weapons control system whatever; yet plans were in hand to integrate air-to-air and air-to-surface weapons on the aircraft. This is evidenced not only by OKB-115 documents but also by a series of presentations for the Soviet government, high-ranking Ministry of Aircraft Industry (MAP – *Ministerstvo aviatsionnoy promyshlennosti*) officials and military top brass, during which the aircraft carried various weapons on two wing hardpoints. Still, the Yak-36's thrust/weight ratio and ordnance load were so low that series production of this complex and expensive aircraft was obviously inexpedient.

More test hovers were made between April and August 1965. Control and stabilisation of the aircraft during vertical take-off and landing was exercised both automatically and manually (with the automatic stabilisation system disabled). The flights showed that the pilot could easily balance the aircraft manu-

Top: '36 Yellow' was preserved at the Soviet Air Force Museum in Monino in an all-blue colour scheme. Above: The machine now has the spurious code '35 Yellow' and Yak-38 style green undersurfaces.

ally, should the automatic stabilisation system fail.

In October 1966 a display of the latest Soviet military aviation hardware was staged at Kubinka airbase about 60 km (37.2 miles) west of Moscow for the benefit of the top government officials of the Soviet Union and its Warsaw Pact allies. By then the Yak-36 was showing quite promising results, so it was included in the display for good measure. Yuriy Garnayev and Valentin Mookhin flew both prototypes ('37 Yellow' and '38 Yellow') to Kubinka AB; one of them was to take part in the flying display while the other aircraft was to be exhibited statically. It so happened that Mookhin had to perform the demonstration flight on 18th October because Garnayev had been dispatched on yet another assignment to a remote location. The Yak-36 came last in the flying display – as the cherry on the cake, so to say. At the designated time the jet taxied out in front of the grandstand where the high-ranking spectators were, turned downwind (this was one of the type's peculiarities – for VTOL operations the Yak-36 had to face downwind, not into the wind like a conventional aircraft) and soared vertically into the air. Next, the machine did a 90° hovering turn and transitioned to forward flight, accelerating to make a circuit of the field. As it passed the grandstand the Yak-36 did a barrel roll at low altitude, then came back, slowed down and hovered right in front of the spectators, concluding the display with a vertical landing.

Apparently the spectators liked the performance. At the banquet that followed, Lt. Gen. A. N. Ponomaryov, the Soviet Air Force Deputy Commander-in-Chief (Armament) – whose brother happened to be a top-ranking government official, a member of the Politbureau – pronounced the obligatory first toast (at official functions, that is) to the health of the Soviet head of state, Leonid I. Brezhnev. The second toast of the day was to test pilot Mookhin, who had received the prestigious Hero of the Soviet Union (HSU) title a while earlier, in June.

The Yak-36's flight test programme lasted nine months. Within this time frame, as in the case of the preceding tethered test cycle, the aircraft was repeatedly modified and refined. As noted earlier, a large recirculation dam hinged at the rear and deployed hydraulically was installed under the extreme nose; it was separated in two by the nosewheel well and carried the nose gear doors, as well as a pair of longitudinal strakes. Still, this feature did not cure the exhaust gas ingestion problem completely.

On 9th July 1967 the Yak-36 created a veritable sensation by appearing at the grand airshow staged at Moscow-Domodedovo airport on occasion of the October Revolution's forthcoming 50th anniversary. This was the first time the Soviet VTOL jet was displayed in public. Again, both prototypes were involved; on 7th July Valentin Mookhin ferried the two aircraft from Zhukovskiy to Domodedovo where they were parked on a remote hardstand. This time the reason why both aircraft were present was different; General Designer Aleksandr S. Yakovlev could not risk having his aircraft miss the show, so one of the aircraft would be a stand-in if the other should go unserviceable. This precaution was justified, as it turned out. Before the show, Mookhin had made nine training flights to practice his display at Zhukovskiy and one more at Domodedovo in '37 Yellow' during the dress rehearsal of the flying display. On the day of the show, however, it was '38 Yellow' that made the demo flight in. Taking off vertically, the aircraft did a slow 360° turn in the hover – a 'waltz for the audience', then transitioned to level flight, making a circuit of the airfield, and proceeded to make a smooth vertical landing. The performance thrilled the public and caused great interest on the part of the foreign visitors, including the military attachés who invariably attended such events. Little did they know that just one day earlier Mookhin had suffered a minor mishap in the first prototype, which had to be repaired on the double, as both machines were required to be airworthy for the flying display. Yet, someone decided to play safe and the undamaged second prototype was flown at the show.

At Domodedovo Yak-36 '38 Yellow' carried a pair of UB-16-57U FFAR pods painted Dayglo orange. The project also envisaged a built-in GSh-23L cannon (which was never fitted). Yet, as noted earlier, the Yak-36 was virtually useless as a combat aircraft; its flight performance was fairly low and its thrust/weight ratio did not allow it to lift a respectable payload. At a take-off weight of 11,700 kg (25,790 lb) without external stores, the machine had a maximum speed of 1,009 km/h (627 mph), a service ceiling of 12,000 m (39,370 ft) and a range of 370 km (230 miles).

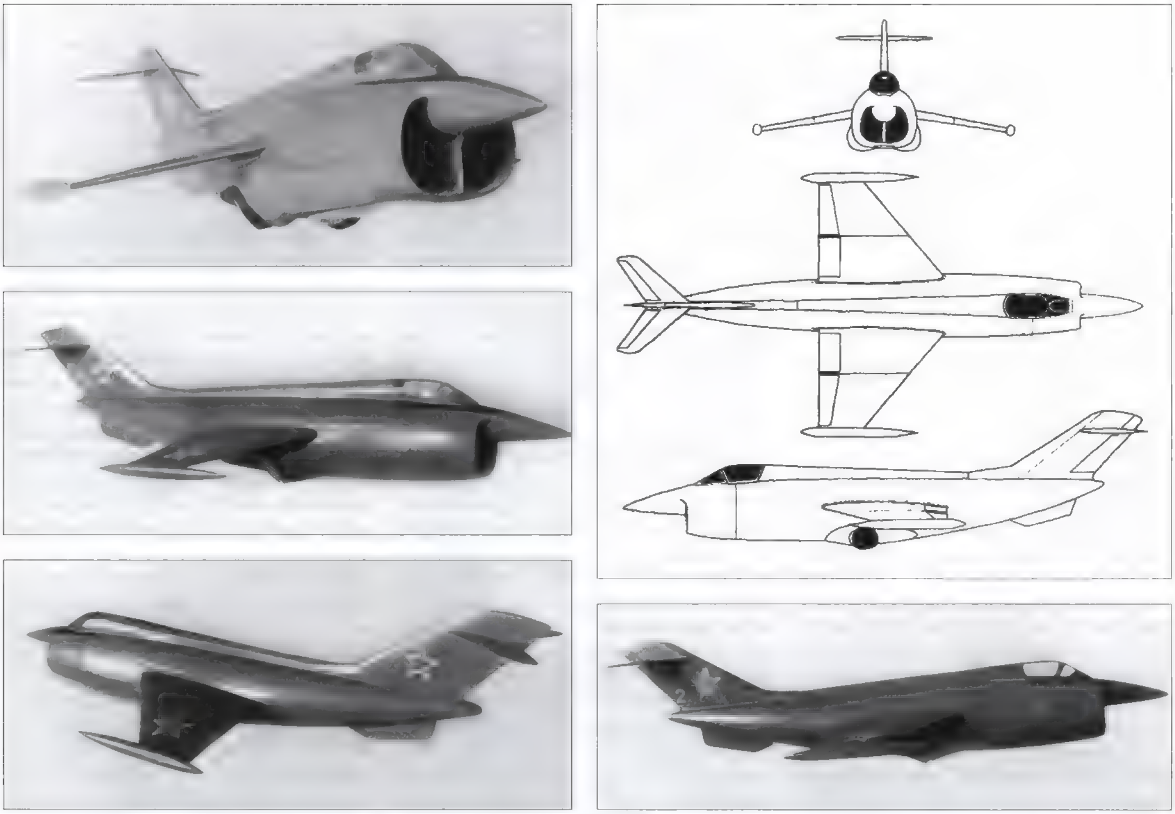
This is how Valentin G. Mookhin recalled the 1967 airshow: *'Shortly before the [air] parade I was summoned by a KGB officer who asked me whether it was dangerous to demonstrate this aircraft at the event. I replied that I could not give a 100% safety guarantee (hardware is hardware, after all), but the machine was no worse than any other aircraft from a reliability standpoint. Still, in the interests of flight safety I requested that the areas over which the aircraft accelerated to minimum control speed* (in forward flight – *Auth.*) *be kept clear of spectators. He promised me they would be.*

On the day of the parade I arrived [at the airport] well in advance and contacted the chief of the KGB directorate. I intended to take a ride around the field with him in his car and show the areas that I wanted to be kept clear of the public. However, that day the security passes had been changed, and the security personnel on site tried to detain us several times. It took some time to sort out this mess, and when we finally got to the spot from where the aircraft was to take off, those areas were thick with spectators. The KGB officer only shrugged – there was nothing to do now.

It was a fine warm summer day, and a gentle sun was shining. In accordance with the order of the parade both Yak-36s were parked on a taxiway about 100 m [330 ft] from the VIP grandstand for the members of the government. At the prearranged time I climbed into the cockpit of the aircraft coded '38', turned on the radio and checked the stopwatch (used for timing the display routine – *Auth.*) *The radio was silent – there was not a soul on air. Each participant of the parade was strictly following the schedule and doing his display programme which had been polished to perfection before the event. When the time was right I started the engines and waited for the moment when I was due to take off. Nearby, at my four o'clock, mechanic Dmitriy Kolotoorskiy started up the engines of the other Yak-36 (coded '37'). Should my aircraft suffer a malfunction [before take-off], I could quickly [shut down and] climb into the other aircraft; this is how it was usually done [at air displays] – just in case. Yuriy Garnayev had been scheduled to fly the back-up aircraft, but he was still on detachment in France at the time.*

Exactly at the designated time I performed a vertical take-off. As I climbed, my heart missed a beat – there was a huge crowd of spectators in festive attire in the area over which I was supposed to accelerate the aircraft. When the aircraft reached an altitude of 5 m [16 ft], I armed the automatic ejection system (as the flight manual required), climbed to 50 m [164 ft] instead of the usual 20 m [65 ft] and initiated forward flight, accelerating and climbing away above the spectator area. I felt awful; should an emergency occur at that moment, I would be punched out and would survive while the aircraft would very probably drop in the midst of the spectators. I went through the display programme in forward flight mode, then decelerated to zero speed, hovering – again at higher-than-usual altitude, – executed a 180° turn in the hover and landed.

A while later a car drove up from the command post of the parade; I and several other pilots participating in the parade were obliged to climb in, and we were taken to the VIP grandstand – right as we were, with no chance to change from our leather flying jackets into more appropriate clothes. There we were introduced to the nation's leaders – Brezhnev, [Chairman of the USSR Supreme Soviet's Pre-



The Yakovlev OKB attempted to turn the Yak-36 into a true combat aircraft. In so doing the forward fuselage was considerably lengthened and the cockpit was moved forward to improve the field of view. The resulting project version illustrated by a model and a three-view drawing was designated Yak-36-70.

sidium Nikolay V.] Podgornyy and [CofM Chairman Aleksey N.] Kosygin. After the parade, a banquet for the government members took place in the airport administration building. I was accosted by many foreign pilots who had been invited to watch the parade and by the military attachés from several nations. Everyone was thrilled by the Yak-36, which had made its public debut.'

When the western world became aware of the Yak-36's existence, the NATO Air Standards Co-ordinating Committee (ASCC) assigned the reporting name *Freehand* to the aircraft.

After the Yak-36's spectacular performance at Domodedovo, General Designer Aleksandr S. Yakovlev approached the government, requesting that an initial batch of ten or twelve Yak-36s be produced at MAP's aircraft factory No. 292 in Saratov, southern Russia. This production plant was a long-standing partner of OKB-115, having built Yakovlev fighters since the Second World War. Yakovlev cited the need to practice shipboard operations with VTOL aircraft as the motive behind his request. By then, however, the Yak-36's uselessness due to its negligible ordnance load had become obvious, and less than six months after the Domodedovo airshow the Soviet government let loose with a directive requiring the Yakovlev OKB to design and build a more capable VTOL combat jet.

By 5th March 1968 the two Yak-36 prototypes had made 419 flights between them; 250 of these were performed by Valentin G. Mookhin. The flight tests showed that an aircraft with the powerplant layout chosen for the Yak-36 was fairly difficult to balance in VTOL modes and during transition to and from level flight. Therefore, further work on the type came to a standstill after the airshow.

The three Yak-36s had different fates. The ground test article ('36 Yellow') was donated to the Soviet Air Force Museum (now called the Central Russian Air Force Museum) in Monino south of Moscow in an overall blue colour scheme. The first prototype ('37 Yellow') was used in 1972 to explore the effect of a VTOL fighter's exhaust jets on the future Type 1143 (*Kiev* class) aircraft carrier. To this end a mock-up section of the carrier's flight deck was built, on which the Yak-36 sat with engines running. The acoustic and thermal loads caused by the exhaust jets were measured in the bays below the deck.

The second prototype ('38 Yellow') served as a trainer for practicing VTOL and hovering techniques; it was flown by Mikhail S. Deksbakh, Leonid Rybikov, A. P. Bogorodskiy and other test pilots preparing to fly the forthcoming 'second-generation' VTOL jet. The training was quite intensive; Deksbakh alone made 17 flights in this aircraft between November 1970 and February 1971. Unfortunately, in February 1971 Rybikov touched down with an excessive sink rate after performing yet another hover and wrecked the aircraft. The pilot was unhurt but the machine was written off.

Chapter 2 relates the development history of the Yak-36M – the first Soviet VTOL combat aircraft which, despite the similar designation, was totally unrelated to the original Yak-36 *sans suffixe*. However, the latter served as the basis for a number of projects that never reached the hardware stage. Even when the decision to build the Yak-36M featuring a mixed powerplant (one lift/cruise engine and two lift engines) had been taken, Leon M. Shekhter's PD team persisted with projects featuring lift/cruise engines only – all derived from the Yak-36 sans suffixe. These are listed here.

Specifications of the Yak-36

Length, including nose boom	17.0 m (55 ft 9$^{13}/_{64}$ in)
Height on ground	4.5 m (14 ft 9$^{11}/_{64}$ in)
Wing span	10.0 m (32 ft 9$^{45}/_{64}$ in)
Wing area, m2 (sq ft)	17.0 (182.79)
Empty weight, kg (lb)	5,300 (11,680)
Take-off weight, kg (lb)	8,900 (19,620)
Fuel load, kg (lb)	2,600 (5,730)
Maximum speed, km/h (mph)	900 (559)
Service ceiling, m (ft)	12,000 (39,370)
Hovering ceiling, m (ft)	1,900 (6,230)
Rate of climb, m/sec (ft/min)	140 (27,550)
Effective range, km (miles)	370 (230)

Yak-36-70 Light VTOL Strike Aircraft (project)

One of the projected derivatives of the Yak-36 *sans suffixe* was a light attack aircraft designated Yak-36-70; the '-70' was a reference to the year of development. The project was completed on 1st July 1970. The aircraft retained the predecessor's basic layout; however, the fuselage nose was appreciably longer, the cockpit was moved forward and the long outrigger boom carrying the forward reaction control nozzle was replaced by a short conical fairing incorporating the nozzle. The engine mounts were redesigned and the air intake was reshaped. The centre fuselage incorporated an additional 500-litre (110 Imp gal) fuel tank and a bay for a GSh-23L built-in cannon, with an ammunition supply of 200 rounds; the tailcone carrying the rear reaction control nozzle was also reshaped. The aircraft was to feature two new Tumanskiy turbojets with vectoring nozzles delivering 7,000 kgp (15,430 lbst) apiece; which would give the machine a thrust/weight ratio of 1.3.

The Yak-36-70 was to have longer range and a higher speed as compared with the predecessor. The aircraft would feature a state-of-the-art navigation/attack avionics suite allowing it to conduct low-level penetration of enemy air defences, navigate to the designated target area and return to base. The ordnance totalling between 1,000 and 2,000 kg (2,205-4,410 lb) was to be carried on four underwing pylons. To extend range, provisions were made for carrying two drop tanks holding 500 kg (1,102 lb) of fuel each.

Yak-36-70F Light VTOL Fighter (project)

The Yak-36-70 evolved into a fighter version designated Yak-36-70F; the PD project was completed on 25th June 1970. This aircraft was optimised for intercepting aerial targets doing up to 2,000 km/h (1,242 mph) at altitudes between 300 and 20,000 m (980-65,620 ft); it could operate as a close air support (CAS) aircraft for ground forces and as an escort fighter for strike aircraft. It could also be used as a strike aircraft for destroying small and mobile targets in the enemy's tactical and theatre-tactical areas, performing anti-shipping strike missions and neutralising the enemy's defences against maritime assault groups. Strike missions would be performed in direct visibility conditions.

The Yak-36-70F had mid-set low aspect ratio wings, conventional tail surfaces and a bicycle landing gear. This time, however, the wings could be folded to save hangar space during below-deck stowage on a carrier, hence the outrigger struts were located at mid-span, not at the tips. As on the Yak-36-70, the cockpit was located well forward to provide a good field of view.

The powerplant comprised two afterburning turbojets acting as lift/cruise engines with vectoring nozzles (hence the F for *for**sazh*** – afterburning); the afterburners could be engaged in forward flight only. Unlike the Yak-36, the aircraft featured two lateral air intakes with movable semi-conical centrebodies reminiscent of the Dassault Mirage or the Lockheed F-104 Starfighter. A reaction control system was used in VTOL/hover and transitional flight modes. The OKB intended to equip the Yak-36-70F with a fire control radar and an optical sight. Bombs, missiles and unguided rockets were to be carried on four underwing pylons. A built-in cannon was also provided; this, along with air-to-air missiles, was to be the fighter's main weapon in the air defence role.

Yak-36A Light Multi-Role VTOL Aircraft (project)

In 1970-71 the Yakovlev OKB undertook preliminary studies of one more VTOL aircraft designated Yak-36A. This was to be a shipboard aircraft based on the above project but powered by new R-49V turbojets offering higher thrust. The avionics suite was also new.

Another view of the Yak-36-70 desktop model, showing to advantage the redesigned nose, the fat spine aft of the cockpit and the neat nosecone incorporating the forward puffer instead of the Yak-36's distinctive 'matchstick'.

Chapter 2

The Naval Yak is Born

Yak-36M Experimental VTOL Strike Aircraft (*izdeliye* V)

In the second half of the 1950s both the western world and the communist bloc were both very active developing missile systems. It was then that missile submarines armed with sea-launched ballistic missiles (SLBMs) made their appearance. The NATO's missile submarines represented a major threat, compelling the Soviet Union to develop new anti-submarine warfare (ASW) cruisers with long range relying on shipboard helicopters as their main means of detecting and destroying hostile subs.

The Leningrad-based TsKB-17 (*Tsentrahl'noye konstrooktorskoye byuro* – Central Design Bureau No. 17) of the Ministry of Shipbuilding brought out the Type 1123 'large ASW ship' better known as the *Moskva* (Moscow) class helicopter carrier. In addition to anti-shipping missiles and depth charges, the ship had a complement of Kamov Ka-25 ASW helicopters; these operated from a flight deck occupying the entire rear half of the hull, which was unusually broad-beamed. (Shortly afterwards, TsKB-17 was renamed NPKB – ***Nev**skoye **proyekt**no-kon**strook**torskoye **byu**ro*, the Neva Project & Design Bureau, thus named after the Neva River on which Leningrad (now St. Petersburg) is located.)

The first Type 1123 carrier, SNS (Soviet Navy ship) *Moskva*, was commissioned in 1967, entering service with the Black Sea Fleet; sister ship SNS *Leningrad* was already under construction at the time. Thus was born a tradition – all Soviet aircraft carriers were named after major Soviet cities. As SNS *Moskva* commenced her seagoing trials, TsKB-17 was already working on the third ship in the series, SNS *Kiev*, which was to be laid down in 1968 and incorporate various refinements.

However, the successful presentation of the Yak-36 VTOL aircraft made the Soviet Navy change their minds. It showed the feasibility of developing a true VTOL combat aircraft which, if used by the Naval Aviation, could expand the capabilities of ASW ships considerably. Therefore the plans to build a third Type 1123 ASW carrier were abandoned; instead, SNS *Kiev* was to be built as the first ship of a new series (Type 1143, or *Kiev* class). This was a larger ship featuring an angled flight deck and a superstructure offset to starboard (a so-called island); its carrier wing was to comprise both helicopters and VTOL strike aircraft. Concurrently, at the suggestion of Marshal Dmitriy F. Ustinov, who was then Defence Industry Secretary with the Communist Party Central Committee, the Yakovlev OKB was tasked with developing a VTOL combat aircraft. (Ustinov subsequently became Minister of Defence.) The Soviet Navy Commander-in-Chief Adm. Sergey G. Gorshkov supported the idea.

The project, which received the provisional service designation Yak-36M (*modernizeerovannyy* – updated) and the in-house product code *izdeliye* VM (that is, *izdeliye* V *moderni**zee**rovannoye*), followed two parallel lines of development. On the one hand, the designers tried to make the most of the basic Yak-36's layout with two lift/cruise engines and turn the machine into a true combat aircraft. At the same time, however, they were working on a very different aircraft with a mixed powerplant featuring a single lift/cruise engine at the rear and two lift engines ahead of the wings.

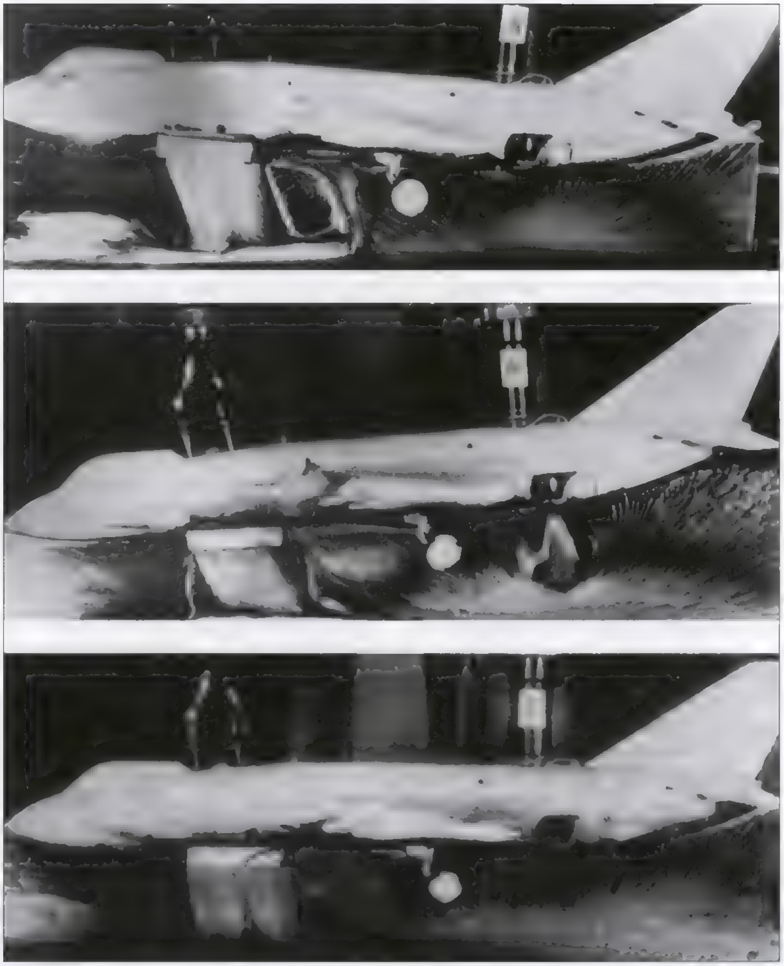
Each of the two versions entailed major technical problems that had to be overcome. Using the same engine(s) for both lift and forward propulsion meant that its thrust (or their aggregate thrust) was to exceed the aircraft's gross weight, otherwise the machine would be unable to take off vertically. On the other hand, such a high thrust/weight ratio was not required for forward flight. The opposite approach was to use separate engines for lift and for cruise flight. This design philosophy – exemplified by the French Dassault Mirage IIIV and Dassault Balzac V experimental VTOL fighters and the British Short SC.1 technology demonstrator – was made possible by the advent of the small and lightweight Rolls-Royce RB.108 turbojets developed specifically as lift engines. It allowed conventional aircraft to be transformed into VTOL aircraft fairly easily and enhanced flight safety, facilitating the transition from vertical to forward flight and back. Yet there was a price to pay – the extra weight of the lift engines which were of no use in cruise flight.

There was also a third option – a mixed powerplant with a lift/cruise main engine. As compared to the mixed powerplant described above (with a cruise-only main engine), this layout required fewer lift engines to provide the requisite thrust/weight ratio in VTOL mode, thus reducing the weight penalty in level flight. This meant the thrust rating of the main engine could be chosen to suit the cruise mode best. The main problem was to choose the general arrangement minimising the thrust losses in VTOL mode.

By the time OKB-115 began development of the Yak-36M the merits and weaknesses of the various powerplant arrangements were already known, as virtually every possible layout for a VTOL aircraft had been studied on western 'jump jets'. Work on the PD project commenced in June 1967 under the direction of Stanislav G. Mordovin (the Yak-36M's project chief) and project engineer O. A. Sidorov.

The 'customer' (the Soviet Ministry of Defence) wanted a light attack aircraft that would have VTOL capability and be supersonic into the bargain. The latter requirement was one of the key factors in the choice of the Yak-36M's powerplant layout. Using a single lift/cruise engine with four vectoring nozzles patterned on the Harrier's Rolls-Royce Pegasus was considered inexpedient. No such engine existed in the Soviet Union, and developing it from scratch would be an extremely lengthy affair. Besides, despite all its merits, such an engine could not provide the required supersonic performance. The RR Pegasus was a turbofan with a fairly high bypass ratio, the fan and bypass duct supplying the forward pair of nozzles and generating nearly 50% of the thrust. Hence the velocity of the exhaust jet was fairly small as compared to a conventional turbojet; as the flight speed grew, the thrust would decrease and the drag would grow. Fitting an afterburner would be the obvious solution, but on an engine with vectoring nozzles it would be a major technological challenge.

After considering all the pros and cons, Mordovin concluded that a mixed powerplant with a lift/cruise engine at the rear and two lift-jets at the front was the best choice if the new VTOL combat aircraft was to be created within the shortest possible time frame, using the available resources. However, General Designer Aleksandr S. Yakovlev favoured the single lift/cruise engine concept. He was supported in this view by PD section chief Leon M. Shekhter and the OKB's chief aerodynamicist Gheorgiy N. Pul'khrov, who opposed



Above: This sequence shows a model of the Yak-36M with air ejectors emulating the engines' operation being tested in the TsAGI towing basin to investigate the spray patterns during overwater flight.

One of the Yak-36M's preliminary design projects bore a striking resemblance to the HS P.1127. This Yakovlev OKB drawing shows the control system runs and reaction control puffers and air ducts.

Mordovin's ideas fiercely; it took a lot of persuasion to win them over.

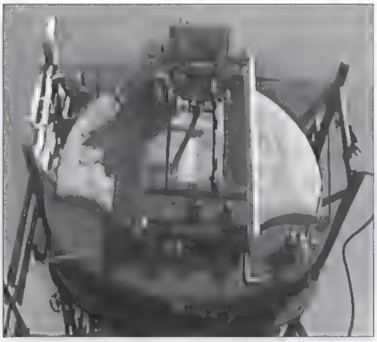
In the autumn of 1967, when the tests of the Yak-36 *sans suffixe* were virtually completed, the latter aircraft's project engineer Viktor N. Pavlov also joined the Yak-36M design team. It was this trio (Mordovin, Sidorov and Pavlov) that bore the brunt of the PD stage work, developing the Yak-36's general arrangement, internal layout and basic systems. Mordovin personally did a complete set of aerodynamic calculations.

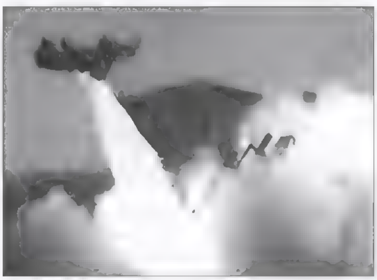
At the General Designer's orders the OKB's specialists stayed away from the work on the version with a mixed powerplant, concentrating on the officially supported version of the Yak-36M (*izdeliye* VM) – the aircraft with two lift/cruise engines that was a direct evolution of the Yak-36 *sans suffixe* (*izdeliye* V). This project envisaging the use of two R27VM-300 engines was duly completed in May 1968, the documents being endorsed by Leon M. Shekhter and Ghennadiy N. Pul'khrov who headed the design effort.

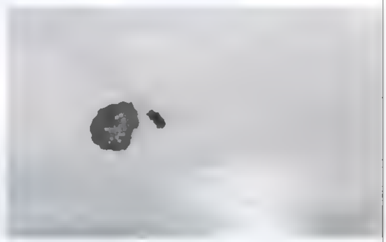
The project documents defined the Yak-36M as *'a light VTOL attack aircraft intended for detecting, identifying and destroying small-sized targets (including moving ones) in the enemy's tactical and close theatre-tactical areas, attacking maritime surface targets and neutralising the enemy's anti-assault assets'*. The aircraft was also to be capable of combating certain types of aerial targets – helicopters and transport aircraft. The Yak-36M was to fly its missions at low altitude, engaging targets within visual range.

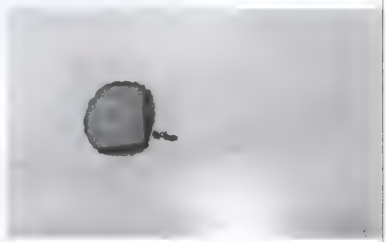
The aircraft was to be capable of operating from shore landing pads as small as 15 x 15 m (49 x 49 ft) or from a Type 1123 aircraft carrier (the project was drafted in the days when the future SNS *Kiev* was still under development to Type 1123 specifications). Short rolling take-offs from and landings on dirt and grass strips were also possible, providing the bearing strength was at least 5 kg/cm^2 (71 lb/sq in).

As noted above, initially the Yak-36M was to feature two R27V-300 turbojets with vectoring nozzles rated at 6,150 kgp (13,560 lbst) for take-off. The specified take-off weight was 10,600 kg (23,370 lb); the maximum speed at 200 m (660 ft) was estimated at 1,250 km/h (776.7 mph) and the range at low altitude as 480 km (298 miles). Later, the Yak-36M was to be reengined with uprated R27VM-300s delivering 6,560 kgp (14,460 lbst) apiece, which would permit an increase of the TOW to 11,200 kg (24,690 lb) and allow the aircraft to reach a maximum speed of 2,000 km/h (1,242 mph) at 10,000 m (32,810 ft). Like the basic Yak-36, in VTOL and STOL modes the aircraft was controlled by means of reaction control nozzles (puffers) at the wingtips, in the extreme nose and in the tailcone.



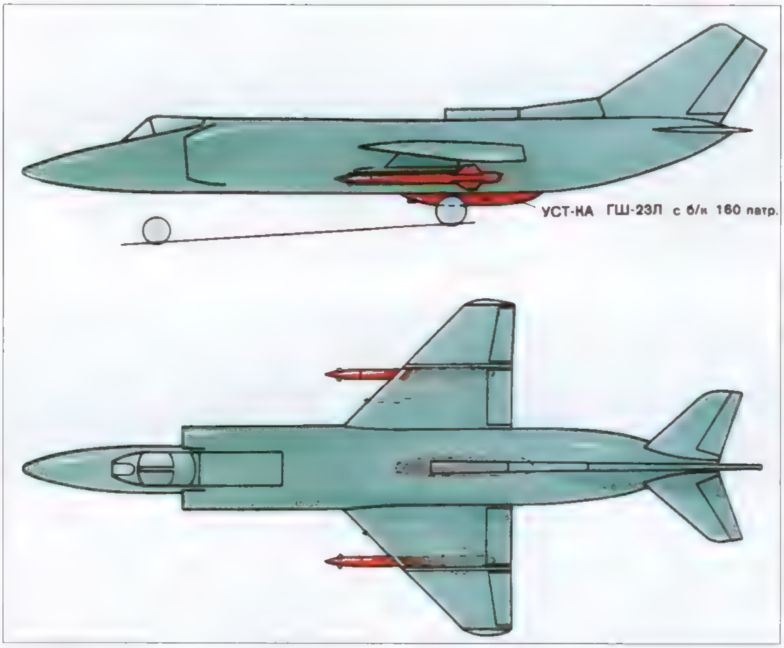






Left row, top/second from top: The same fuel system test rig was used in the development of the Yak-36M. Left and above: These sequences show the SK-E automatic ejection system being tested as the KYa-1 ejection seat is fired at different angles and the pilot parachutes to safety.

In attack configuration the Yak-36M was to carry 1,000 kg (2,205 lb) of ordnance on four wing pylons in the case of a VTOL mission profile; resorting to a STOL technique allowed 1,500 kg (3,310 lb) of ordnance to be carried. The weapons options included UPK-23-250 cannon pods, UB-32 rocket pods with 57-mm (2.24-in) S-5 FFARs and B-8M 20-tube rocket pods with 80-mm (3.15-in) S-8 FFARs, as well as 240-mm (9.44-in) S-24 heavy unguided rockets on individual launchers. Free-fall weapons were bombs of up to 500 kg (1,102 lb) calibre and ZB-360 napalm tanks (*zazhi**gah**tel'nyy bahk* – lit. 'incendiary tank'). On counter-air missions the Yak-36M was to carry R-3S (NATO code name AA-2 *Atoll*) IR-homing short-range air-to-air missiles; a built-in 23-mm (.90 calibre)

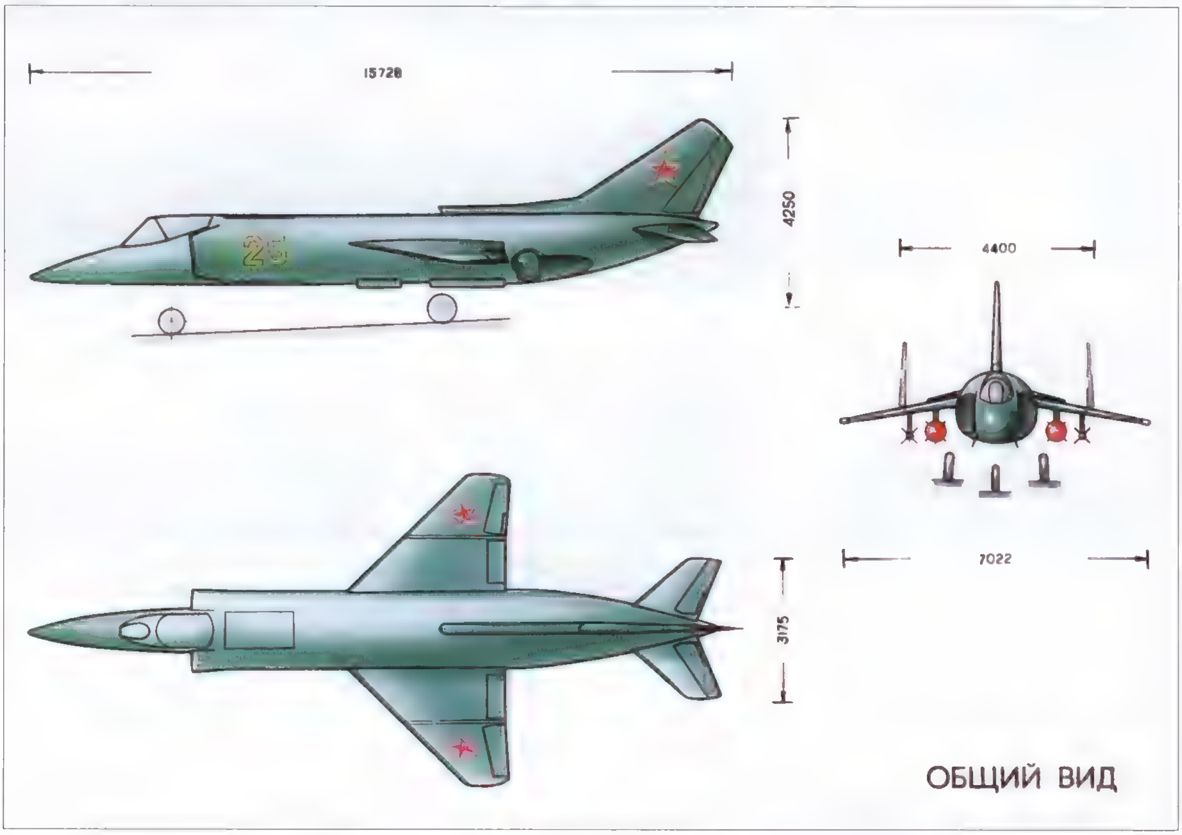


Above: A drawing from the Yak-36M project documents showing how two Kh-23 air-to-surface missiles and a VSPU-36 pod housing a GSh-23L cannon with 160 rounds were to be carried.

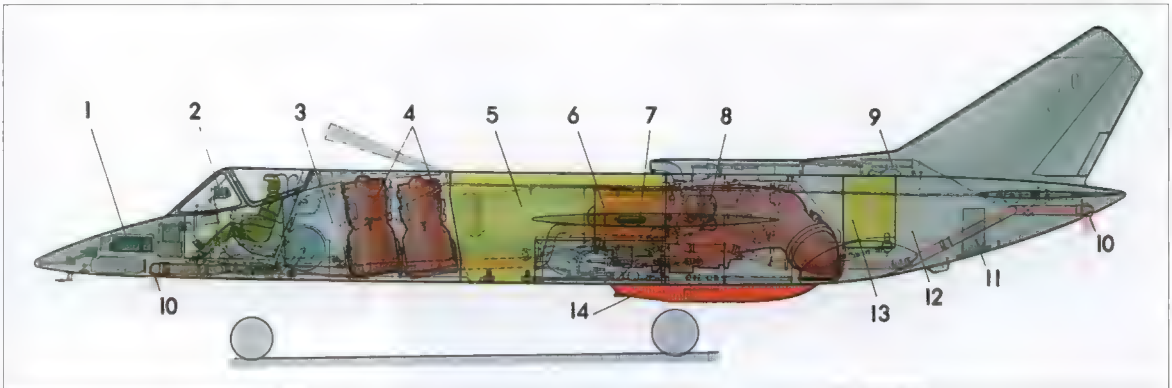
GSh-23L cannon with 200 rounds was also envisaged. For self-defence, provisions were made for installing a Siren'-FSh (Lilac; pronounced *seeren'*) active electronic countermeasures (ECM) pack at the expense of a reduction in the weapons load.

The comparative strengths and weaknesses of the two alternative projects were weighed up at a session of MAP's Scientific & Technical Council. To the surprise of the General Designer, the Council preferred Mordovin's mixed-powerplant version over the evolutionary twin-engined project which he favoured. The Council ordered the OKB to draft a Council of Ministers directive that would officially sanction the development of the Yak-36M; the OKB's partner enterprises in the development effort, as well as the timescale for prototype construction and the aircraft's submission for joint State acceptance trials, were to be set out in this draft.

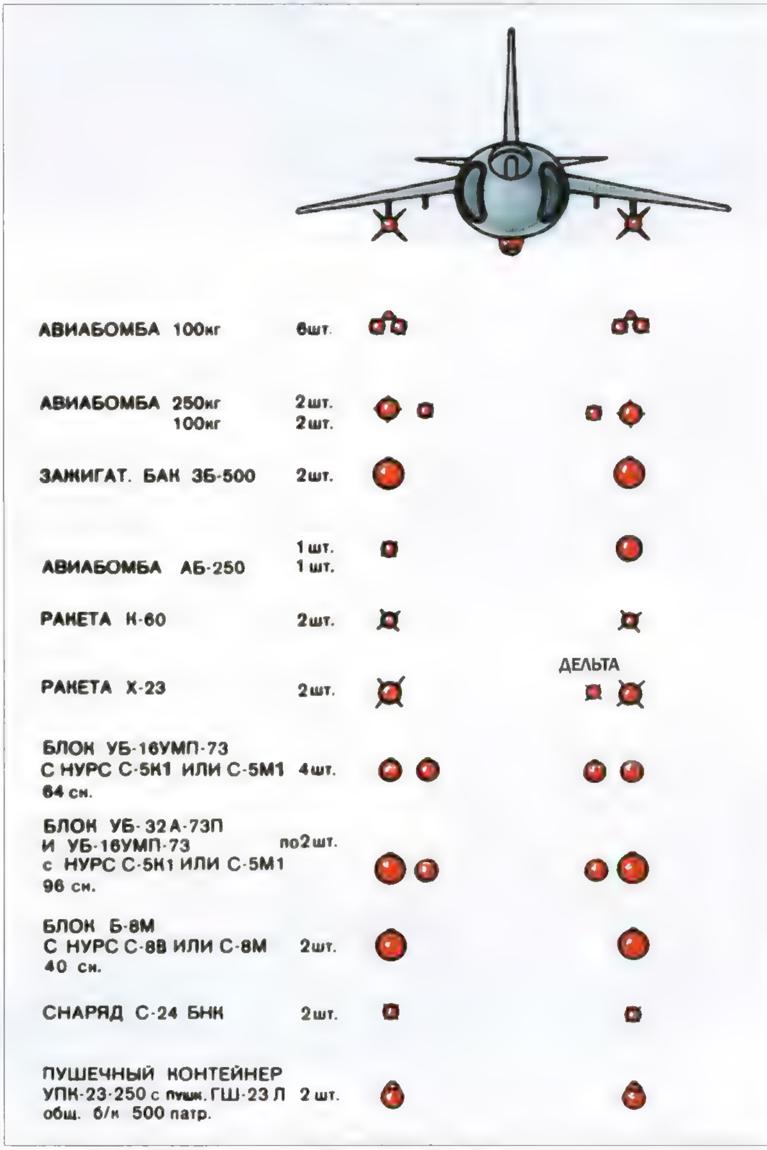
On 27th December 1967 the Communist Party Central Committee and the Council of Ministers issued directive No. 1166-413 tasking the Yakovlev OKB with designing, building and testing the Yak-36M light VTOL attack aircraft. The directive also envisaged development of a two-seat conversion trainer vari-



A three-view of the Yak-36M from the ADP documents. Note the definitive nose style (the upper drawing shows the second prototype) and the recirculation dams. The aircraft is 51 ft 7 7/32 in long and 13 ft 11 21/64 in tall, with a stabiliser span of 10 ft 5 in; the wing span is 23 ft 0 29/64 in or 14 ft 5 15/64 in with the wings folded.



Above: A drawing from the ADP documents showing the Yak-36M's internal layout. The key to the drawing is:
1. SAU-36 automatic control system modules;
2. ASP-PF-7M gunsight; 3. Forward equipment bay;
4. RD36-35FV lift engines inclined 10° forward;
5. No. 1 fuel tank; 6. R27V-300 lift/cruise engine;
7. Oxygen bottle; 8. Hydraulic tank; 9. BU-150 hydraulic elevator actuator; 10 Front and rear reaction control nozzles; 11. Brake parachute housing; 12. Rear equipment bay; 13. No. 2 fuel tank; 14. Conformal cannon pod



Right: The external stores options envisaged by the ADP. Top to bottom:
100-kg (220-lb) bombs (six, on multiple racks);
250-kg (551-lb) bombs outboard/100-kg bombs inboard (two each);
ZB-500 napalm tanks (two)
K-60 air-to-air missiles (two)
Kh-23 missiles (two plus Del'ta guidance system pod inboard);
UB-16UMP-73 rocket pods with S-5K1 or S-5M1 FFARs (four/64 rounds);
UB-32A-73P and UB-16UMP-73 rocket pods (two each) with S-5K1 or S-5M1 FFARs (98 rounds);
B-8M rocket pods with S-8V or S-8M FFARs (two/40 rounds);
S-24BNK unguided rockets (two);
UPK-23-250 cannon pods with GSh-23L cannons (two; total ammunition supply 500 rounds).

ant and, in the more distant future, of a fighter version. Aleksandr S. Yakovlev did not endorse the design documentation completion schedule for the Yak-36M (*izdeliye* VM) proper and for the test rigs to be designed for it until 29th August 1968. This is when development of the new aircraft began in earnest.

OKB-115 started issuing the technical documents for the mixed-power jet in September. Project engineer Viktor N. Pavlov was responsible for the advanced development project (ADP) work, Deputy General Designer Stanislav G. Mordovin being assigned overall responsibility for the programme.

It took a full year to draw up the specific operational requirement (SOR) for the Yak-36M and have it approved by the Air Force and the Navy. On 7th January 1969 the

Above: A model of the Type 1143 aircraft carrier with a squadron of Yak-36Ms and a Kamov Ka-25 helicopter on the flight deck.

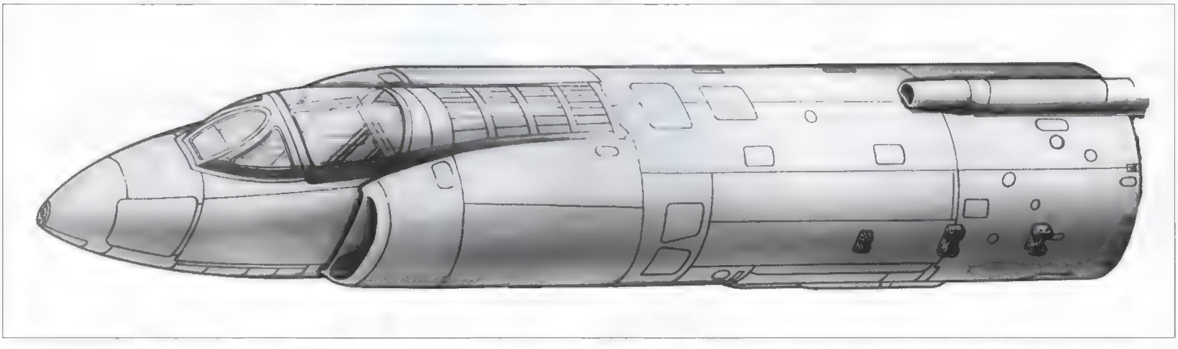
SOR for the 'Yak-36M light VTOL attack aircraft powered by one R27V-300 lift/cruise engine and two RD36-35FV lift engines' was approved by the Commander of the Soviet Naval Aviation (AVMF – *Aviahtsiya Voyenno-morskovo flota*); actually it was his next-in-command, N. A. Naumov, who signed the document. Finally, on 25th January the SOR was endorsed by the Soviet Air Force C-in-C Air Marshal Konstantin A. Vershinin.

According to the SOR the Yak-36M was intended for close air support (CAS) of ground troops in the enemy's tactical and close theatre-tactical areas – that is, up to 150 km (93 miles) from the forward edge of the battle area. When operating from Type 1123 aircraft carriers the Yak-36M was to attack surface ships and shore targets and perform reconnaissance sorties. Its principal role was the destruction of stationary and mobile ground and maritime (surface) targets within visual range; it was also to be used against enemy transport, ASW and airborne early warning (AEW) aircraft and helicopters.

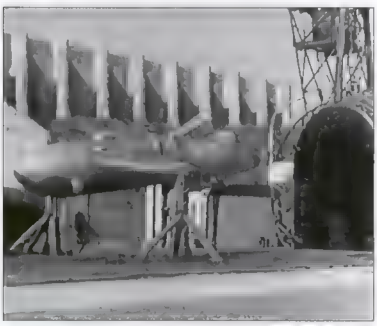
The performance stipulated in the SOR was quite similar to the figures stated for the design performance figures of the alternative (twin-engined) Yak-36M. Thus, the maximum speed was to be at least 1,250 km/h (776.7 mph) at 200 m (660 ft) and at least 1,400 km/h (870 mph) at higher altitude. Effective range with a 1,000-kg (2,205-lb) warload was to be at least 700-750 km (435-466 miles) in the event of a vertical take-off in international standard atmosphere (ISA) conditions), or at least 1,400 km (870 miles) when cruising at 900-950 km/h (559-590 mph) and 10,000-12,000 m (32,810-39,370 ft). A separate clause stipulated the ability to operate from unpaved strips with a bearing strength of 5 kg/cm² (this included short take-offs and landings, taxiing and towing). Depending on the ambient conditions, the ordnance load for a VTOL mission profile was to be 1,000 kg (2,205 lb) in ISA conditions or 600 kg (1,320 lb) if the outside temperature was +30°C (86°F) and the atmospheric pressure was 740 mm Hg. In the event of a rolling take-off from a dirt strip (with a take-off run of no more than 200 m/660 ft) the ordnance load would be increased to 1,500 kg (3,310 lb).

The SOR also stated: *'The aircraft's weight and dimensions shall be optimised for operation from Type 1123 ships and be agreed with the NPKB of the Ministry of Shipbuilding, which is now developing the third ASW ship with aircraft armament'.* The latter phrase actually means 'ship carrying shipboard aircraft'. The SOR also contained clauses concerning the aircraft's reliability and maintenance-friendliness (in terms of man-hours), as well as a list of avionics, equipment and compatible weapons. The Yak-36M had four wing hardpoints which were to be used for carrying bombs, napalm tanks, various unguided rockets (in pods or on individual launchers), Kh-23 anti-shipping missiles, K-13 (alias R-3S) AAMs and UPK-23-250 cannon pods. The customer also demanded that the machine should have two *izdeliye* 225P built-in cannons with an ammunition supply of 80 rpg.

The navigation/attack suite featured an ASP-17BMTs computing gunsight (*aviatsionnyy strelkovyy pritsel*) linked to a PBK-3 bomb sight. The latter model, which was borrowed from the Sukhoi Su-17 shore-based fighter-bomber, was optimised for the lob-bombing technique that allowed the machine to approach the target covertly at ultra-low altitude, then zoom up and release the bomb in the middle of a half-loop before making off (hence the PBK for *pritsel dlya bombometahniya s kabreerovaniya* – bomb sight for bomb delivery in a climb). Until the nav/attack suite had been perfected, however, the first three

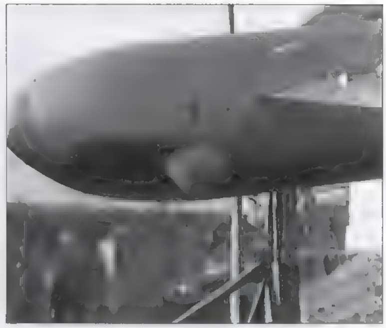


A drawing of the Yak-36M's forward fuselage from the ADP documents. Note the very short and blunt nosecone as used on the DLL engine test rig and the *izdeliye* EVM (the full-scale mock-up and the first prototype). Note the wing spar attacment fittings.



Yak-36Ms were to be fitted with the ASP-PF gunsight borrowed from the MiG-21PF interceptor and the PBK-2 bomb sight, and the sensors linked to these provisional sights were to be replaced. Provisions were made for installing the Del'ta-N command link system providing radio command line-of-sight guidance for the Kh-23 ASM.

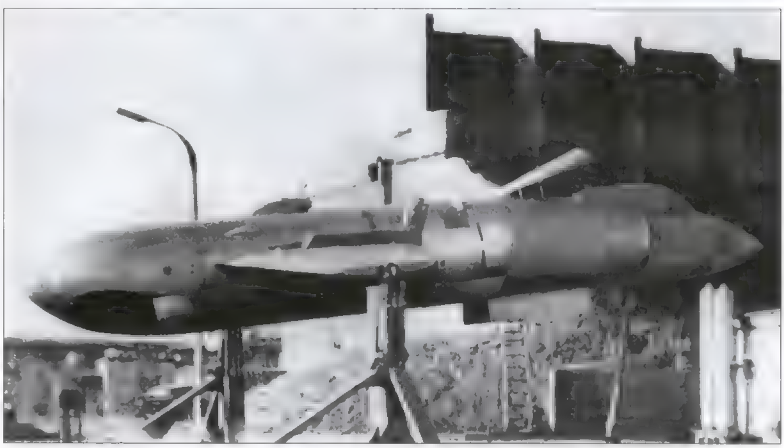
OKB-115 worked jointly with virtually all of the research institutions in the MAP framework before choosing the Yak-36M's layout.

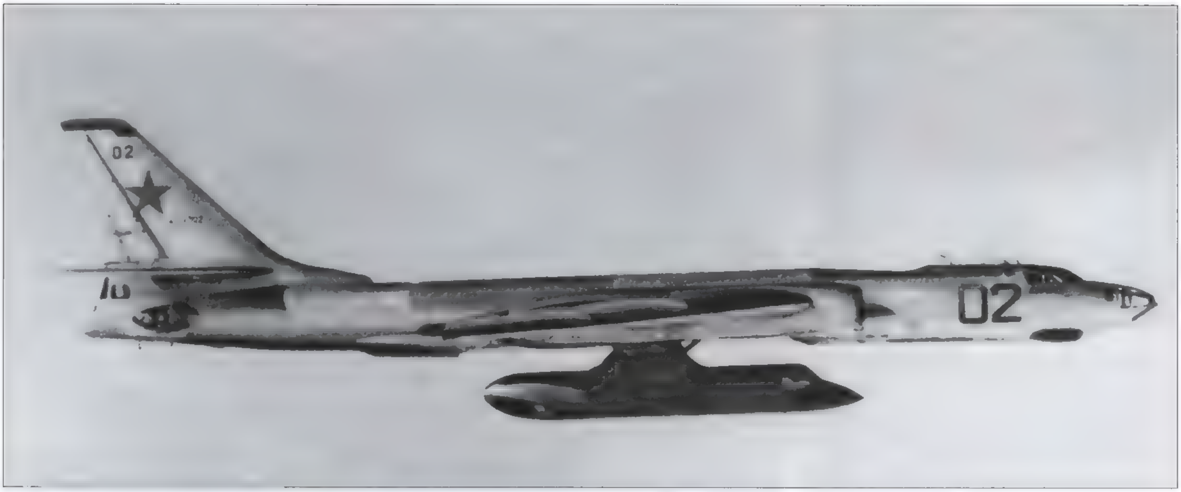


The choice of the engine types turned out to be the toughest problem. After much deliberation the designers chose to retain the proven Tumanskiy R27V-300 as the main engine. Since it was now housed on the fuselage centreline, the lift/cruise engine had to be modified: the single large vectoring nozzle gave place to a bifurcated jetpipe with downward-angled 'trouser legs' terminating in small vectoring nozzles. Yuriy I. Goosev was the engine's project chief at the Tumanskiy OKB. The RD36-35FV turbojet developed by the Rybinsk-based OKB-36 headed by Pyotr A. Kolesov was chosen as the lift engine; Kolesov's deputy A. Dynkin led the development of this engine.

At the Yakovlev OKB, Mordovin's team did a huge amount of work selecting the powerplant layout of the *izdeliye* VM, calculating its parameters and doing the design job. This called for close cooperation with the two engine makers. OKB-300 had to make sure that the lift/cruise engine had an adequate gas dynamic stability margin so that it would run stably when the vectoring nozzles were rotated into the vertical thrust position. The

Left: The propulsion test rig (a Yak-36M fuselage cropped aft of the main engine nozzles) undergoes tests in the T102 wind tunnel at TsIAM. Note the short nose, the metal cockpit canopy and the stub wings.
Top: The nozzle of one of the lift engines.
Right: This sequence shows how the lift/cruise engine are vectored.
Below: Another view of the rig propped up on supporting struts, with the lift engine doors open.





Above and left: Later, the propulsion rig was modified – the stub wings were removed and a massive double pylon was added on top. With the help of this pylon it was attached to a Tu-16LL engine testbed coded '02 Blue' (c/n 4201002). Called DLL, the rig was semi-recessed in the Tu-16LL's bomb bay on the ground and lowered clear before the R27V-300 engine was started.

Kolesov OKB had to enable the lift engines to run at different power settings and ensure an adequate engine lift; fact is, the RD36-35 had originally been designed as an expendable engine with cruise missiles in mind, and its service life was unacceptably short.

The main (lift/cruise) engine was accommodated in the centre/rear fuselage, just aft of the aircraft's CG; the vectoring nozzles were buried in special recesses in the rear fuselage underside featuring heat shields. It breathed through two oval-section intakes flanking the forward fuselage. The two lift engines were housed in a special bay immediately aft of the cockpit (which was located well forward to provide a good field of view over the pointed nose), their axes being inclined 10° forward. Both lift engines had fixed (non-vectoring) nozzles but the nozzle of the rear engine was inclined 5° forward with respect to the engine axis so that the efflux of the two engines merged into a single jet; this improved the distribution of the exhaust gases in VTOL modes. The lift engines breathed through a large scoop-type air intake which opened hydraulically for take-off and landing, closing flush with the upper fuselage in level flight; the intake door incorporated a number of spring-loaded suction relief doors. The exhaust port of the lift-jets was closed by a pair of lateral doors. The lift engines were started by compressed air bled from the main engine.

Of course, the Yak-36M featured a reaction control system for balancing the aircraft in VTOL and transitional flight modes; the puffers were located ahead of the cockpit, aft of the rudder and at the wingtips. The front and rear puffers were mechanically linked with the rudder, providing yaw control as well as pitch control. The air bleed from the main engine's compressor for the reaction control system reduced the engine thrust, so the puffers were directed downwards in order to recoup the thrust losses as much as possible.

Considering that the aircraft was powered by three engines of two different types which had very different dynamic parameters, a special algorithm of controlling the mixed powerplant needed to be developed in order to avoid creating a thrust imbalance. On the Yak-36M all three engines were controlled by a single throttle via hydromechanical actuators, without the benefit of an automated electronic control system. Much later, when the Yak-36M (Yak-38) was no longer top secret, a British Aerospace test pilot who had flown the Harrier had a chance to get a close look at the 'Soviet Harrier'. He rated the Yak's engine control system as 'an amazing achievement in hydromechanical control technology'.

The engine control mechanism created by the Yakovlev OKB after a determined design effort was a system of summators and variable gearing ratio drives which were linked to work according to a certain algorithm. One mechanism added up the inputs from the lift engine control lever ('start up/shut down'), from the autopilot servos and from the main throttle. The resulting motion was transmitted to the control levers of the lift engines' fuel control unit (FCU). A second summator added up the inputs from the throttle and the servos, transmitting the result to the main engine's FCU. The control inputs were transmitted to all three engines only if the lift/cruise engine nozzles were deflected downward at any angle from the cruise flight position. The gearing mechanisms altered the proportion of the control inputs transmitted to the lift engines and the main engine as the latter's nozzles moved from the cruise position to the vertical thrust position. This mechanism (not a 'complex electronic control system', as purported by the western aviation

press of the day) was developed by the Yak-36M's project chief Stanislav G. Mordovin himself with assistance from Viktor N. Pavlov and M. P. Rybchenkov; the three of them received a Soviet patent for this.

The SAU-36 automatic control system (*sistema avtomaticheskovo oopravleniya*) was developed to alleviate the pilot workload, performing the following functions:

• enhancing pitch and roll control in manual control mode during vertical take-off and landing;

• stabilisation of pitch, bank and heading with respect to the neutral position while hovering over land or water;

• stabilisation of pitch, bank and heading in forward flight;

• damping of pitch and roll oscillations in forward flight;

• bringing the aircraft into straight and level flight with autostabilisation of heading and altitude, should the pilot become disoriented;

• stabilisation of barometric altitude;

• recovery from unsafe altitude as commanded by the radio altimeter/ground proximity warning system;

• automatic pitch stabilisation in forward flight when the engine power setting is changed;

• limitation of G loads during vertical manoeuvres at critical angles of attack;

• indication of the principal flight and navigation parameters.

The SAU-36 also enabled automatic landing approach and approach in flight director mode, using the short-range radio navigation (SHORAN) system, guiding the aircraft automatically along the desired descent trajectory. Additionally, it was to monitor the serviceability of the aircraft's vertical gyros. The SAU-36 had a health and usage monitoring system continuously checking its serviceability and alerting the pilot of any malfunctions. The automatic control system was to be activated at any pitch or bank angle, requiring no prior adjustment. Eventually, however, some of the SAU-36's planned features proved impossible to implement.

The Yak-36M's avionics and equipment were accommodated in two bays in the forward fuselage (fore and aft of the cockpit) and a third bay in the rear fuselage, just aft of the lift/cruise engine nozzles. The Del'ta-N guidance system for the Kh-23 missile was to be carried in an underwing pod.

As mentioned earlier, the original plans called for installing two *izdeliye* 225P cannons in the wing roots. In May 1970, however, the Air Force insisted that the cannon should be located under the fuselage and the Gryazev/ Shipunov GSh-23 cannon be used for the sake of commonality between various aircraft. Hence the SOR was revised to include the VSPU-36 cannon installation (***vstroyennaya pushechnaya oostanovka*** – built-in cannon installation for the Yak-36) with an ammunition supply of 160 rounds.

The Yak-36 was to have a conventional airframe structure made of aluminium alloys. The mid-set trapezoidal wings had 45° leading-edge sweep and 10° anhedral. The outer wings folded vertically upwards to save space during on-deck parking or hangar stowage. The tail surfaces had a conventional layout. Unlike the predecessor, the Yak-36M had a tricycle landing gear with an aft-retracting single-wheel nose unit and forward-retracting single-wheel main units.

Yakovlev aircraft had always been characterised by a high degree of refinement from a structural weight standpoint. The structural weight issue loomed large when the VTOL combat jet was being designed; a few dozen extra pounds here and there – and the aircraft might prove unable to leave the ground. Hence the OKB began a determined effort to fight excess weight, even calling a competition for the best weight-saving ideas (with money prizes as an incentive). To save weight the designers made large-scale use of 01420 grade aluminium-lithium (Al-Li) alloy which was lighter and offered a higher specific strength as compared with the traditional D16T duralumin and V95 aluminium alloy. The introduction of the new structural material was not trouble-free, but the concerted efforts of the OKB's Research & Development Complex, Chief Technologist's Department and the prototype construction facility eventually bore fruit – the Al-Li alloy was successfully mastered. This was the time when many fresh ideas and unusual design solutions were born. For instance, hydraulic drives section chief Varvara V. Selivanova suggested using jet fuel as the working medium in the Yak-36M's hydraulic actuators instead of the usual oil-type hydraulic fluid; she also obtained approval for this solution from the subcontractor enterprises developing the hydraulic actuators.

The answers to many of the questions arising in the course of the design work could not be found by means of the good old pen and paper. Quite a few test rigs and benches had to be developed and built in the process, notably:

• the propulsion test rig;

• the 'cable crane';

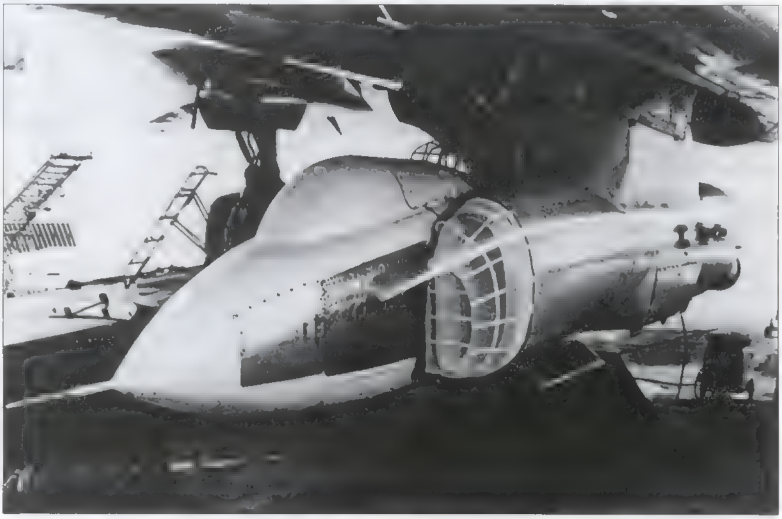
• the SSM dynamometric rig;

• the crew rescue system test rig based on a swivelling platform that emulated the aircraft's motion in the event of a reaction control system failure;

• the reaction control system test rig.

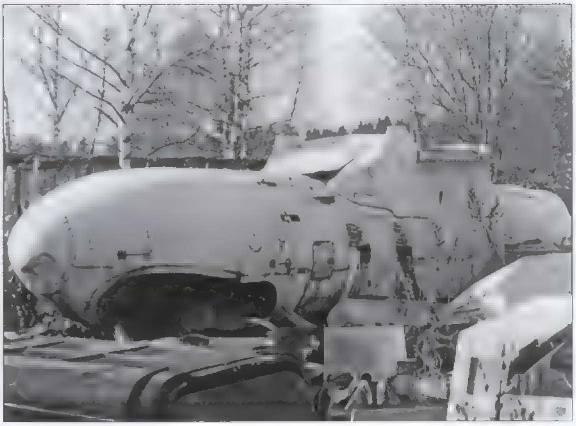
The aforementioned 'cable crane' had been built by LII for the institute's own needs, being used for testing various types of aircraft; it was ideally suited for testing the VTOL jet in hovering and low-altitude manoeuvring modes.

The propulsion test rig represented a clipped Yak-36M fuselage (with inner wings but no tail unit) featuring the main and lift engines, their control system and various ancillary systems. For starters, this 'abbreviated' Yak-36M underwent tetsing in the T-102 wind tunnel operated by TsIAM's Turayevo division; the concerted operation of the three engines and their control system was checked and the engines were started at simulated flight speeds up to 300 km/h (186 mph). Next, the Yak-36M fuselage was delivered to Zhukovskiy and suspended (minus stub wings) beneath one of the Tupolev Tu-16LL engine testbeds operated by LII ('02



Close-up of the DLL suspended below Tu-16LL '02 Blue'. Note the foreign object damage FOD prevention screens installed for ground runs of the engine.





The DLL ended up on the dump at Kubinka AB where the Yakovlev OKB maintains a storage facility. Note the detachable panels giving access to the test equipment.

Blue', c/n 4201002), commencing a series of flight tests at speeds in excess of 300 km/h. On the ground the assembly was semi-recessed in the Tu-16's former bomb bay, being lowered clear before engine starting. In this guise the propulsion test rig was designated DLL (***dvig**atel'naya **leta**yuschchaya laborato**riya*** – engine testbed). Boris A. Orlov (LII) was engineer in charge of these tests, with V. V. Korolyov as mechanic.

The reaction control system test rig served for determining the required amount of engine bleed air, verifying the reaction control puffers and choosing their optimum location. Rig D mentioned in the introduction served for exploring the exhaust jet distribution pattern in take-off and landing modes.

The SSM dynamometric rig was built somewhat later, serving for exploring the forces to which the VTOL aircraft would be subjected during vertical take-off and landing, as well as for assessing the efficiency of the reaction control system. The Yak-36M's deputy project chief V. K. Svetozarskiy headed the design effort on this rig; the manufacturing drawings were issued by a team under V. T. Mishin. The first SSM rig had been built back in 1964 for the Yak-36 sans suffixe; for the very different Yak-36M a second example had to be designed. The SSM served for testing the recirculation dams designed to protect the air intakes and prevent exhaust gas ingestion and for selecting the optimum forces created by the reaction control puffers. The first of these rigs was located at Zhukovskiy; later, the Saratov aircraft factory and the Soviet Air Force's Red Banner State Research Institute named after Valeriy P. Chkalov (GNIKI VVS – *Gosoo**dar**stvennyy na**ooch**no-is**sled**ovatel'skiy krasnozna**myon**nyy insti**toot** Vo**yen**no-voz**doosh**nykh seel*) built their own SSM rigs.

The Yak-36M's stability and handling were checked, using a computerised flight simulator. This comprised a cockpit section mounted on a platform that could swivel around three axes, emulating the aircraft's manoeuvres, the powered flight control system, an autopilot and an Elektron computer. A special indicator screen gave the pilot an idea of the aircraft's attitude. This flight simulator also served as a teaching aid for training Yak-36M pilots in VTOL and hovering techniques.

Yak-36P VTOL Interceptor (project)

In parallel with the Yak-36M strike aircraft the OKB was working on an interceptor version designated Yak-36P (*pere**khvat**chik* – interceptor). Unlike the basic aircraft, which could operate in visual meteorological conditions only, this was an all-weather combat aircraft that was to feature a redesigned nose housing a fire control radar. Importantly, the Yak-36P was to have a new lift/cruise engine developed by the Tumanskiy OKB, then known as *izdeliye* 79 (it was subsequently designated R79V-300). Also, since the heavy radar increased the take-off weight a good deal, the interceptor was to have three lift engines instead of two.

When the Yak-36M entered flight test, the Yak-36P project was reworked considerably, emerging eventually as a rather different VTOL fighter – the Yak-41 (see Chapter 6).

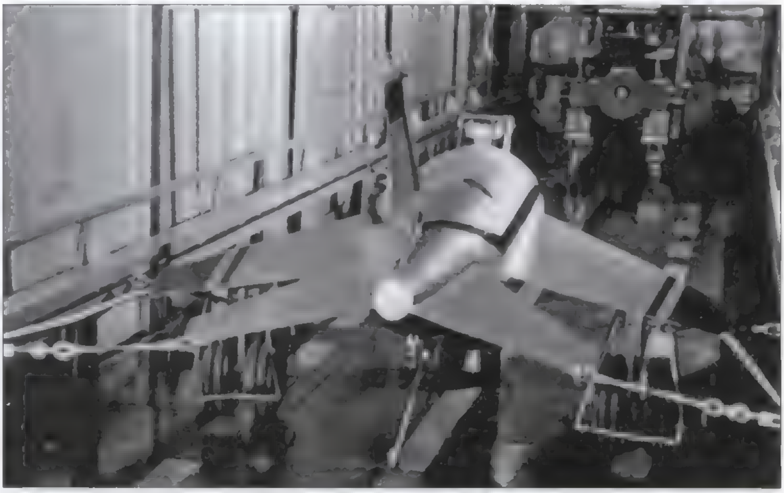
Chapter 3

Tests and Production

Yak-36M Attack Aircraft Prototypes (*izdeliye* EVM, VM-1, VM-2, VM-3 and VM-4)

On 23rd January 1969, two days before the endorsement of a new SOR and just six months after development of the *izdeliye* VM was started, the Yakovlev OKB's prototype construction facility (MMZ No. 115) cut the first metal on the first prototype Yak-36M and the first wood on a full-size mock-up of same. (Yes, construction of the first prototype and the mock-up began concurrently!) The mock-up and the actual aircraft were outwardly identical, differing from subsequent examples in having a short ogival nosecone and a horizontally cropped fin tip. A revised nose was already under development, to be incorporated on subsequent examples; therefore, the mock-up and the first prototype were known in-house as *izdeliye* EVM, the E standing for *eksperimentahl'noye* – experimental.

In early March 1970 the Yak-36M's ADP and full-size mock-up were carefully examined by the mock-up review commission. The latter included the leading specialists from the Soviet aircraft industry's main R&D institutions (TsAGI, LII, TsIAM, GosNII AS, NIAT, VIAM) and from the Yakovlev OKB's subcontractors responsible for the engines, automatic flight control system, crew rescue system and data recording system. Incidentally, the mock-up was still half-finished at the time; it was not completed until 15th April. (Note: GosNII AS = State Research Institute of Aircraft Systems (*Gosoodarstvennyy naoochno-issledovatel'skiy institoot aviatsionnykh sistem*). NIAT = Aviation Technologies Research Institute (*Naoochnyy institoot aviatsionnykh tekhnologiy*). VIAM = All-Union



Above: This dummy equivalent dimensionally and in weight to the Yak-36M was built for checking how the aircraft would fit in the ship's hangar.

Above and with: '01 Yellow', the *izdeliye* EVM full-size presentation mock-up of the Yak-36M shows off the short nose, strong wing and tailplane anhedral, horizontally clipped fin tip and narrow landing gear track. There are no recirculation dams yet.

Close-up of the Kh-23 missile and the UPK-23-250 cannon pod under the mock-up's port wing.

Top, right, and top right: '05 Yellow', the first prototype Yak-36M (the VM-1), on the 'cable crane' at Zhukovskiy. It, too, represented the short-nosed/square-tailed.EVM configuration. Note the 'Danger, air intake' warning triangles, the tethering cables and the sensor cable leading to remote data recorders. Above: The VM-1 is towed at Zhukovskiy. Note the plain air intakes without splitter plates or blow-in doors. Above right: The first prototype undergoing tests on the SSM dynamometric rig.

Institute of Aviation Materials (*Vsesoyooznyy institoot aviatsionnykh materiahlov*) developing and testing structural materials.)

The Air Force also evinced an interest in the programme, and in April 1970 the Air Force C-in-C Air Marshal Pavel S. Kutakhov paid a visit to the Yakovlev OKB, accompanied by Deputy C-in-C (Armament) Gen. A. N. Belyunov. By then the mock-up and the actual prototype had been completed; both were painted in a dark blue naval colour scheme, wearing the tactical codes '01 Yellow' (the mock-up) and '05 Yellow'.

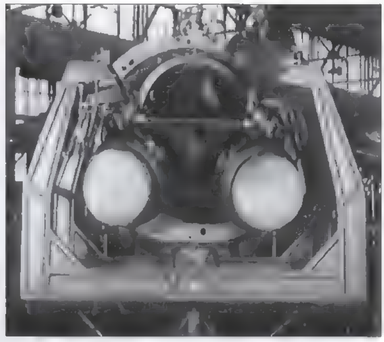
The presentation was made by General Designer Aleksandr S. Yakovlev himself; the OKB's chief test pilot Valentin G. Mookhin also made a report at the presentation, as did the senior military representative (that is, the MoD quality control officer) Lt. Col. Yuriy A. Loonyov. Being a former service pilot, Kutakhov wasted no time climbing into the cockpit of the *izdeliye* EVM to check out the cockpit ergonomics and the field of view, while Mookhin and Loonyov stood on stepladders on either side of the cockpit, answering the C-in-C's questions. One of the questions was addressed to Mookhin, who, as mentioned in Chapter 1, already held the HSU title at the time.

'How long will it take to accelerate to cruising speed after take-off?' – Kutakhov asked.

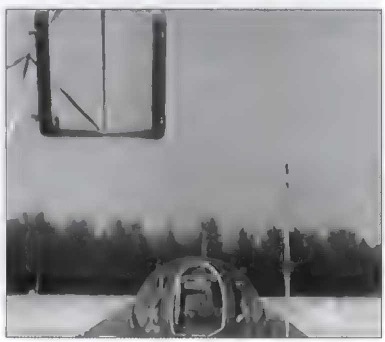
'The estimated time is between 1 minute 40 seconds and two minutes' – was Mookhin's reply.

'Look, hero, if you manage to do it, you can look forward to a second "star" – the C-in-C promised, referring to the Gold Star Order that went with the HSU title.

A few days later, at the end of April, a second mock-up review commission convened; this time it was made up of Air Force and Navy representatives and chaired by AVMF Vice-Commander Gen. N. A. Naumov. Again, the commission was allowed to examine both the full-size mock-up and the real thing. As it always happens, the commission pointed out several deficiencies and signed a protocol calling for their elimination. In particular, the military demanded that the KYa-1M ejection seat developed by OKB-115 (hence KYa for ***kres**lo **Ya**kovleva* – 'Yakovlev seat') be



Far left and above left: The second prototype (VM-2) seen during final assembly.
Above: The R27V-300 engine is fitted to the VM-2.
Left: This view of the first and second prototypes shows the VM-2's long nose. The different attitude of the machines is due to the fact that the VM-2's main gear oleos are charged to maximum pressure.



Centre left and above: The VM-2 ('25 Yellow') undergoes tests on the SSM rig. showing the original nose shape (long but still upturned) and the old squared-offtail. Note the fixture for the 'cable crane'.
Centre: The second prototype in cruise flight.
Centre right: The VM-2 was fitted with FOD protection grilles at some stage of the tests.
Right and above: The second prototype was also used for testing the canopy jettison system. Here the canopy is jerked away by a special cable.

The VM-2 is shown here with the later pointed nosecone (instead of a rounded dielectric cap) and two dummy Kh-23s. Note the overall blue finish.

replaced with the K-36 zero-zero ejection seat developed by OKB-918, which was specified as the standard ejection seat for all new Soviet combat aircraft. (Until the late 1960s the Soviet aircraft design bureaux developed ejection seats in house. Later this task was entrusted to OKB-918 under Chief Designer Guy I. Severin – now called NPP *Zvezda* ('Star' Research & Production Enterprise) – which specialised in crew rescue systems and in-flight refuelling systems.) After a deal of discussion the designers and the customers agreed that the K-36 seat would be fitted from the 11th production aircraft onwards.

Another subject that caused a lot of discussions was the lateral visibility from the cockpit, which was pronounced inadequate. The designers promised to improve it by lowering the cockpit sills.

The forthcoming manufacturer's flight tests were an extremely important stage involving a considerable risk. All of the Yak-36M's systems had been tested time and time again on ground rigs, but they had been tested separately; now was the time to see how they worked in concert, and in flight.

The reaction control system developed by a team under G. A. Bykovskaya required major revisions; some of its key components had to be totally redesigned and tested anew, causing the test schedule to slip. The landing gear, too, provided a few nasty surprises – in particular, a lot of effort was required to get the nosewheel steering mechanism up to scratch.

In spite of these troubles, on 15th May 1970 – exactly one month after the completion date – the first prototype Yak-36M (*izdeliye* EVM, alias *izdeliye* VM-1) was delivered to the Yakovlev OKB's flight test facility in Zhukovskiy. Initially the aircraft was used for captive tests on the 'cable crane', as the SSM

dynamometric test rig for the Yak-36M was not yet available. Again, Viktor N. Pavlov was the engineer in charge of the tests; B. B. Vorob'yov was the machine's mechanic. During tethered tests the VM-1 hovered at altitudes of up to 5 m (16 ft). This stage, which included exploration of the engines' thermal footprint, powerplant adjustment and checks of the reaction control system, lasted four months.

At length the aircraft was 'unleashed', and on 22nd September 1970 the Yak-36M made its first free hover with Valentin G. Mookhin at the controls. On this first occasion the aircraft rose just 0.5 m (1 ft 7 in) above the ground. A week later, on 29th September, Mookhin performed the second free hover.

These first attempts to become airborne showed that the VM-1 was prone to oscillating, especially in the roll channel. This even resulted to minor damage to the aircraft caused by several hard landings. *Déjà vu* – the same thing had happened with the Yak-36 *sans suffixe*, and the reason was the same – the reaction control system's authority in the roll channel was insufficient. As mentioned in Chapter 2, originally the air jets of the wingtip reaction control nozzles were directed downward; thus it was only one nozzle that created a banking force when the control stick was moved laterally, the nozzle on the other side being simply disabled. The engineers modified the nozzles in such a way that the air stream could be directed upward as well as downward. Now, when the pilot moved the stick laterally the wingtip nozzles operated differentially, which doubled their efficiency without requiring more bleed air.

These pictures show the VM-2 making its first landing on SNS *Moskva* on 18th November 1972.

The design features and handling characteristics peculiar to VTOL aircraft necessitated development of a new flight test technique, calling for stability and handling criteria that were slightly different from those applied to conventional aircraft. Such notable OKB-115 employees as Stanislav G. Mordovin, Kerim B. Bekirbayev, Viktor N. Pavlov and I. N. Krivolutskiy, as well as LII specialists Anatoliy I. Kvashnin and Yuriy I. Sneshko, contributed a lot to shaping these criteria.

Manufacturer's flight tests of Yak-36M '05 Yellow' (the VM-1, or EVM) took place at Zhukovskiy, commencing on 22nd Septem-

The VM-2 is parked on the deck of SNS *Moskva*, with weapons arrayed in front for the Navy top brass (R-3S AAMs, Kh-23 ASMs – dummies in both cases – and UPK-23-250 cannon pods. The aircraft sits on a special steel platform protecting the deck from the jet exhaust (note the solid lines instead of hatched ones).

ber 1970 and lasting until mid-July 1971. This aircraft was used for exploring the VTOL and hover modes. By 2nd December 1970 Valentin G. Mookhin had made 20 vertical take-offs, hovers and vertical landings in it; by 13th July 1971 he performed 18 more such flights.

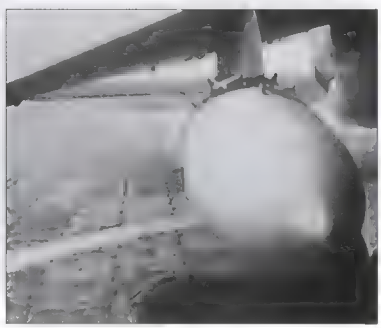
The first prototype also participated in the Yak-36M's State acceptance trials, being used for validating some of the aircraft's systems and for live weapons tests. The VM-1's last test missions were probably the flights made to check the aircraft for electromagnetic compatibility (EMC) with the aircraft carrier. These missions were flown at the Bagerovo test range on the Crimea Peninsula and from the carrier SNS Kiev in 1976.

Meanwhile, on 15th October 1970 – exactly five months after the first prototype – the Yakovlev OKB's experimental production facility completed the second prototype Yak-36M (izdeliye VM-2, c/n 02) which wore the same dark blue finish and the tactical code '25 Yellow'. Unlike the VM-1, this aircraft had a longer, more pointed and drooped nose with a hemispherical tip. By then the SSM dynamometric rig had been completed, so the VM-2 was erected on this rig in order to assess the control characteristics and explore the exhaust gas distribution pattern; the

Left: Yakovlev OKB test pilot Mikhail S. Deksbakh. Below: The ship's crew tosses Deksbakh into the air in a show of enthusiasm after the first landing. Below right: A. V. Dovbnya, the captain of SNS *Moskva*, presents s tailor's striped vest to Deksbakh to indicate he is now 'one of ours'.

Above: The VM-2 is jacked up on the carrier's deck.

Above right: A commemorative photo of the Navy top brass and the directors of military R&D institutions involved in the Yak-36M programme aboard the SNS *Moskva*.



Right: A Kh-23 ASM hooked up to the VM-2 on the carrier's deck.

Far right: A ZB-360 napalm tank on the starboard outer pylon.

Top, above and right: Five aspects of the VM-3 ('55 Yellow'), the third prototype Yak-36M. This machine, too, had a horizontally cropped fin cap and the longer and pointed nose introduced on the VM-2. Note the recirculation dams.

Below right: After retirement the VM-3 was used for ditching tests, being dropped into the water at various angles to see how long it would remain afloat. Note that the tactical code has been removd and photo calibration markings have been applied.

designers paid special attention to the aforementioned suction effect (ground effect) arising at altitudes below 2 m (6.5 ft). G. A. Matveyev was appointed engineer in charge of the VM-2's tests, while Ye. N. Yermolayev was the aircraft's mechanic.

It turned out that the unfavourable interaction between the jet efflux and the airframe ate up about 800 kgp (1,760 lbst) of engine thrust. To minimise the thrust losses the designers installed longitudinal strakes serving as recirculation dams under the fuselage; additionally, the nozzle of the rear lift engine was inclined 15° from the vertical so that the exhaust jets of the two lift engines merged into one.

Once the ground test cycle on the SSM rig was over, the second prototype was cleared for flight tests. On 24th and 25th November 1970 Valentin G. Mookhin made three high-speed taxi runs in '25 Yellow'; on 27th November the machine became airborne for the first time, making a short hop. Shortly afterwards the MAP Methodical Council convened at LII's premises in Zhukovskiy and, after analysing the test results obtained so far, gave the go-ahead for the maiden flight, which was to be performed in conventional take-off and landing mode. Since the Yak-36M's approach speed in a conventional landing was quite high due to the small wing area – 340-360 km/h (211-223 mph) – and the VM-2 was not yet fitted with a brake parachute, it was decided to vector the lift/cruise engine nozzles downward after touchdown to provide a measure of reverse thrust. The Tumanskiy OKB authorised this procedure.

In accordance with this, on 2nd December 1970 the second prototype Yak-36M made its first real flight in CTOL mode with Mookhin at the controls; a Mikoyan/Gurevich MiG-21U trainer piloted by L. D. Rybkin, a LII test pilot, acted as chase plane. By 13th July 1971 Mookhin had made 11 flights in the VM-2, exploring the flight envelope and establishing the corrections that had to be made to the pitot tube readings (calibrating the pitot). In so doing a pointed nosecone was fitted.

Between 22nd September 1970 and 13th July 1971 – the day when the manufacturer's flight tests were completed – the first and sec-

ond prototypes made 49 flights between them. All were performed by Mookhin.

Coded '55 Yellow', the third prototype (izdeliye VM-3, c/n 03) was rolled out at MMZ No. 115 on 16th June 1971. It still had a horizontally cropped tail and shared the VM-2's nose design. On 30th July the aircraft suffered an accident, rolling over during a conventional landing with Yuriy A. Shevyakov at the controls. The mishap was caused by a stiff crosswind, which dragged the machine off the runway, and by the faulty design of the nosewheel steering mechanism which proved unable to counter the drift. Keeping a cool head, Shevyakov acted bravely and efficiently; in the nick of time he managed to shut down the engines and turn off all electric power, thereby preventing a fire.

Still, the VM-3 was extensively damaged and took three months to repair, which meant the second prototype had to shoulder the main test workload. The designers drew the obvious consequences from the mishap; the main landing gear units were redesigned to increase the wheel track from 2.2 m (7 ft 2$\frac{39}{64}$ in) to 2.75 m (9 ft 0$\frac{17}{64}$ in) and the steerable nosewheel was replaced by a castoring one, the aircraft being steered on the ground by differential braking. Additionally, a PTK-36M brake parachute with an area of 13 m² (139.9 sq ft) was provided.

The Communist Party Central Committee/Council of Ministers directive ordering the development of the Yak-36M required the first prototype to be submitted for joint State acceptance trials in the fourth quarter of 1970, the second and third examples following in 1971. The Yakovlev OKB had a reputation for strictly complying with government orders concerning development schedules, and it lived up to this reputation once again: on 28th December 1970 the Yak-36M was officially submitted for State acceptance trials. In accordance with VPK ruling No. 16-1971 the government appointed a State commission chaired by Air Marshal I. I. Borzov for the purpose of holding the trials. After Borzov's death in office in 1974 he was succeeded by Col. Gen. A. N. Tomashevskiy as chairman of the State commission.

A so-called Chief Designers Panel chaired by Kerim B. Bekirbayev was formed at the orders of General Designer Aleksandr S. Yakovlev to coordinate the actions associated with testing and debugging the Yak-36M. The

A Yak-36M prototype (probably the VM-3) displayed with an impressive weapons array at Akhtoobinsk for the military top brass. The weapons include S-24 rockets, S-5 FFAR (and UB-16-57UM and UB-32 pods for same), UPK-23-250 cannon pods, Kh-23 ASMs and bombs.

panel included S. G. Kulagin, Stanislav G. Mordovin, Klavdiya S. Kil'disheva, Gheorgiy N. Pul'khrov and Valentin G. Mookhin. It was authorised to enlist the services of specialists from the leading R&D institutions of MAP (such as TsAGI, LII and TsIAM), as well as from the enterprises responsible for the aircraft's powerplant and principal systems.

On 11th February 1971 Mikhail S. Deksbakh, another OKB-115 test pilot, started preparing to fly the Yak-36M in accordance with the State acceptance trials programme. His training flights started on a small scale but gradually grew more intensive as he mastered new elements of the flight profile. Deksbakh started off with strictly vertical take-offs, hovers and vertical landings; next he began manoeuvring in the hover above the landing pad. On 16th and 18th February 1972, when the State acceptance trials had already begun, Deksbakh started practising the transition from vertical to forward flight, accelerating initially to 50 km/h (31 mph) and then to 100 km/h (62 mph). Satisfied that the pilot was doing just fine, the designers allowed him to proceed to deceleration. On 18th and 21st February 1972 Deksbakh made conventional take-offs, then started the lift engines and slowed the aircraft down – first to 350 km/h (217 mph), then to 200 km/h (124 mph).

Also on 21st February Deksbakh performed a 'half-profile' flight – a vertical take-off followed by a transition to level flight, a circuit of the field and a conventional landing. Finally, on 25th February 1972 he made his first 'full-profile' VTOL flight, showing that he had mastered the aircraft fully.

Stage A of the State acceptance trials officially began on 15th September 1971, continuing until 10th October 1973. All three prototypes existing at the time – the VM-1, VM-2 and VM-3 – were involved in this stage.

In March-April 1972 Mikhail S. Deksbakh flew the first and second prototypes with various external stores as part of the State acceptance trials. First he made vertical take-offs, hovers and vertical landings, then proceeded to fly a 'full-profile' VTOL mission.

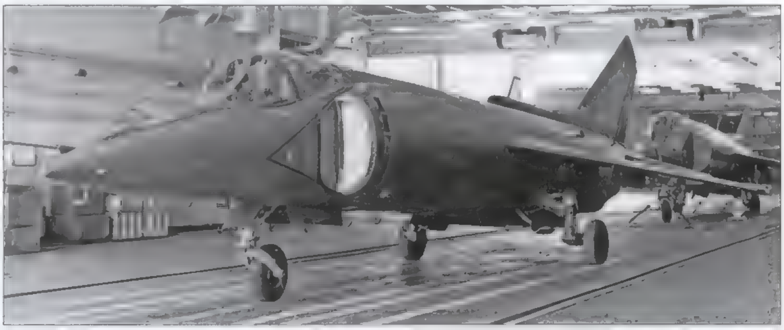
The third prototype was earmarked for live weapons tests as part of Stage A. The tests took place at the main GNIKI VVS facility in Akhtoobinsk (Vladimirovka AB), commencing on 18th April 1973. The following month Yak-36M '55 Yellow' (the VM-3) had the type's first show appearance – it was part of an aviation hardware display at Akhtoobinsk organised for the Soviet government. The 'jump jet' was presented by General Designer Aleksandr S. Yakovlev and the OKB's chief test pilot Valentin G. Mookhin.

The State acceptance trials programme included stability and handling tests with various ordnance loads (in conventional take-off mode) and performance testing of the SAU-36 automatic control system. Additionally, the aircraft's manoeuvrability was assessed, the maximum altitude at which the engines could be restarted was established, and the pitot tube was calibrated. The live weapons tests included gunnery attacks on ground targets, checking the powerplant's operating stability during gunnery and rocket launches (that is, whether blast gas ingestion would cause the engine to surge) and determining the weapons' ballistic parameters.

During the weapons tests the VM-3 was flown by GNIKI VVS test pilots Vladilen P. Khomyakov (project test pilot) and I. I. Shirochenko, as well as by Mikhail S. Deksbakh (OKB-115) and Oleg G. Kononenko (LII). Engineer A. F. Travin supervised the tests and V. V. Korolyov was the aircraft's mechanic.

Testing the Yak-36M turned out to be a difficult task. First of all, the project test pilot had to learn to fly the machine he was to 'teach to fly'. No two-seat version existed yet, and

Above: The fourth prototype (VM-4) on the SSM dynamometric rig; note the sensor cable.



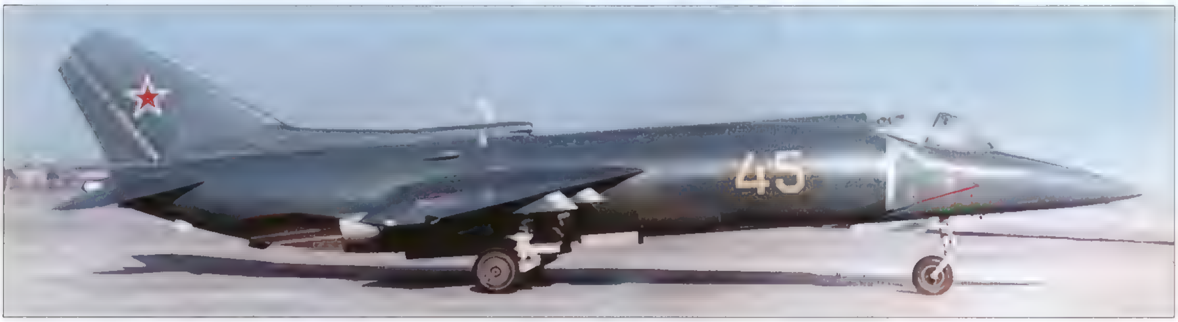
Above: The VM-4 ('45 Yellow') and the uncoded second production Yak-38 (f/n 0201) in the hangar of the carrier SNS *Kiev*. These two aircraft performed a lot of test work together. Note the definitive nose profile.

This view of the VM-4 on the Kiev's deck shows well the raked fin tip introduced on this aircraft and adopted for production.

Khomyakov had to master the 'jump jet' without the benefit of check rides in the trainer. On 17th July 1972 he made his first solo flight in the Yak-36M (in CTOL mode); on 25th July he performed the first two hovers. After practising vertical take-offs/landings and hovers for a while (with Viktor N. Pavlov coaching him on the radio from a mobile command post), on 6th October 1973 Khomyakov successfully performed his first 'full-profile' VTOL flight.

A preliminary report on the results of the trials was duly filed and endorsed by the Air Force C-in-C on 27th August 1973. Stage A was completed in September; on 22nd October 1973 the Vice-Minister of Aircraft Industry endorsed the official trials report.

Once flights over land had been mastered fully, preparations for overwater flights were set in motion. Pursuant to VPK ruling No. 202 dated 28th July 1972 a special test programme (referred to as 'experimental tests') was held as part of the State acceptance trials; this programme involved carrier compatibility tests aboard a Type 1123 (*Moskva*



Top and above: Two more shots of the fourth prototype, showing the definitive nose and tail shape, the revised air intakes (with boundary layer splitter plates and auxiliary blow-in doors), the new wide-track main gear units and the characteristic nose-up ground angle. The forward door of the nose gear unit is missing.

Above: The VM-4 on the deck lift of a Kiev class carrier. The outer wings are vertical when folded.
Above right: The same machine takes off vertically, toting two ZB-360 napalm tanks. Note the temporary airdata probe on top of the nose.

Above: Three FAB-100M54 bombs on an MBD3-U4 multiple ejector rack. Above right: A napalm tank is ready for hooking up.
Far right, above and below: The VM-4 is seen with a large weapons array at a new hardware display for high-ranking military officials.

class) helicopter carrier (aka large ASW ship). To this end the Soviet Navy made the carrier SNS *Moskva* available. A special landing platform was installed in the centre of the ship's flight deck to protect it from the hot jet efflux with which the deck had not been designed to cope. The platform was made of St3 grade steel 10 mm (0 25/64 in) thick, measuring 20 x 20 m (65 ft 7 13/32 in x 65 ft 7 13/32 in).

The first Type 1143 aircraft carrier (SNS *Kiev*) was still under construction at the time. Therefore, in order to check the Yak-36M for compatibility with Kiev class carriers, in 1972 the Black Sea Shipyard in Nikolayev, the Ukraine – the enterprise responsible for the ship's construction – built a section of the carrier's flight deck. As mentioned in Chapter 1, this test rig was constructed at the LII airfield in Zhukovskiy, and the first prototype Yak-36 sans suffixe ('37 Yellow') made engine runs on the 'flight deck' for the purpose of checking the thermal loads. The very first engine runs revealed a problem – the steel deck overheated and buckled; some kind of heat insulation was clearly needed to avoid structural damage to the ship. VIAM stepped in, developing the AK-9F heat-resistant ceramic material; later, the flight decks of all Kiev-class aircraft carriers were covered with AK-9F tiles measuring 550 x 550 mm (1 ft 9 21/32 in x 1 ft 9 21/32 in) and 10 mm thick. The temperature and noise levels in the bays below the flight deck (for example, the hangar) were measured at the same time.

Moreover, the shore-based airmen were confronted with a few peculiarities of shipboard operations that were quite outside their experience; they had to learn how to cope with these new difficulties in the course of the tests. In August 1972 a team of Yakovlev OKB specialists arrived aboard the carrier SNS *Moskva*, which was docked in Sevastopol' on the Black Sea, to handle the issues associated with the Yak-36M's forthcoming deck landing.

The second prototype was assigned to the special test programme, with Mikhail S. Deksbakh as project test pilot. Again, G. A. Matveyev was engineer in charge of the tests, while Ye. N. Yermolayev was the aircraft's mechanic.

Maritime operations called for extreme composure and special psychological training on the part of the pilots. One of the complications was that the ship's deck was perceived by the pilot of an approaching aircraft differently from a shore landing pad of the same size. Therefore Deksbakh had to make several training flights in a Ka-25U dual-control trainer helicopter to master the correct glideslope, with Col. N. P. Prakhov acting as instructor. These flights began in the North Bight of Sevastopol' on 10th November 1972, the pilot using the vertical take-off and landing technique developed for the Yak-36M. The five training flights in the Ka-25U showed that the best approach technique was to approach the carrier from astern, strictly on the hull centreline. Next, SNS *Moskva* weighed anchor and headed towards Kerch-Feodosiya Bay where the rendezvous with the VM-2 was to take place.

On 16th November Mikhail S. Deksbakh made a familiarisation flight over the bay in a UTI-MiG-15 jet trainer. Later that day he made another familiarisation flight in the area – this time in the Yak-36M (VM-2). The following day Deksbakh made a further five training flights in a helicopter, using the chosen technique; this time they took place over the sea in the area where the Yak-36M was to land on the carrier.

One of the problems that cropped up during the tests concerned the ship's air defence radar, which measured the range in fathoms and nautical miles. This was totally unfamiliar for a 'landlubber' pilot who was accustomed

to measuring distances in kilometres. The pilot needed to know when the aircraft came within 6.5-8.5 km (4.0-5.28 miles) of the ship – the point when the lift engines had to be started – and then within 3.5-4 km (2.17-2.5 miles), when it was time to vector the thrust of the main engine and commence the final approach. The Navy resorted to a simple solution – two ships were anchored at appropriate distances from the carrier to act as benchmarks.

In the morning of 18th November 1972 the call went out, 'Prepare the ship for landing!' First, a Mil' Mi-8 helicopter carrying a team of news cameramen and photographers put in an appearance, shuttling back and forth along the Yak-36M's anticipated flight path. Next, a black dot appeared above the horizon, swelling quickly and assuming the contours of an aircraft as it rapidly approached the ship. Mikhail Deksbakh rocked his wings as he passed above the ship; then the aircraft made a combat turn and entered the glideslope, coming in to land. The helicopter assumed a position alongside the Yak-36M

Among other things, the VM-4 served for rough-field tests. The air intakes were fitted with large FOD screens; the open auxiliary blow-in doors are visible. Note the new white dielectric nosecone.

The pilots who tested the Yak-36M. Left to right: Vladilen P. Khomyakov, Viktor V. Vasenkov (both GNIKI VVS), Valeriy V. Nazaryan, Oleg G. Kononenko (both LII) and Yuriy I. Mitikov (Yakovlev OKB).

when the latter was 3-4 km (1.86-2.5 miles) out, keeping formation all the way until the aircraft landed. The exhaust jets kicked up a cloud of fine mist during the approach, creating rainbow-coloured halos around the wings all the while. At length the Yak-36M hovered above the steel landing platform and descended smoothly onto it – the approach had been calculated perfectly.

On 22nd November 1972 Deksbakh flew a 'full-profile' mission from the carrier, taking off vertically from the platform and landing vertically after making a circuit of the ship. Air Marshal Ivan I. Borzov, who witnessed this, instructed the carrier's captain to make an entry in the ship's log reading *'The birthday of shipboard aviation'*. (Fixed-wing aviation, that is; ASW choppers don't count?)

The 'experimental tests' of the Yak-36M aboard the SNS *Moskva* lasted more than a year (from 6th November 1972 to 16th December 1973), proving beyond doubt that VTOL jets could operate both from specialised aircraft carriers and from ordinary merchant ships (bulkers, container ships and the like) equipped with special landing pads measuring 20 x 20 m.

Meanwhile, on 27th March 1973 MMZ No. 115 completed the fourth prototype Yak-36M (*izdeliye* VM-4, c/n 04) – the so-called ***etalon*** (standard-setter) or pattern aircraft for series production. Oddly, it had a lower tactical code than the preceding example ('45 Yellow'); this was probably a ploy meant to confuse hypothetical spies. The VM-4 featured the new wide-track landing gear with a track of 2.75 m (9 ft 0 17/64 in), a further revised nose profile, modified air intakes with boundary layer splitter plates and five auxiliary blow-in doors on each side, a recontoured fin with a raked tip and an avionics fit representative of the production configuration. These avionics were to be verified during Stage B of the State acceptance trials.

Concurrently with the flight tests the aircraft's PNK-36 navigation/attack suite (*prit**sel'**no-navigatsi**on**nyy **kom**pleks*) was put through its paces on a Yak-28U trainer (c/n 3930707) converted into an avionics testbed.

In early July 1973 the second, third and fourth Yak-36M prototypes were demonstrated to top-ranking Soviet government officials during a secret display of new aviation hardware code-named *Roo**bezh**-73* (Frontier-73) that took place at Kubinka AB. LII test pilot Oleg G. Kononenko took part in the flying display at the event, flying the VM-3; Mikhail S. Deksbakh was on stand-by alert with the VM-2, should the third prototype go unserviceable. At that time, A. F. Travin was the engineer in charge and V. V. Korolyov was the prototypes' mechanic.

As the Yak-36M entered flight test, OKB-115 set up test detachments (so-called expeditions) at the 'forward operating locations' where the prototypes were deployed – the main GNIKI VVS facility in Akhtoobinsk (Vladimirovka AB), Feodosiya (Kirovskoye AB), Kerch (Bagerovo AB) and Saki (Novofyodorovka AB). These 'expeditions' comprised test engineers and maintenance personnel.

Stage B of the State acceptance trials took place between 30th January and 10th October 1974, involving the second and third prototypes, which still had the Stage A avionics fit. The trials took place at GNIKI VVS in Akhtoobinsk; V. N. Andronov was appointed engineer in charge of the trials, while Vladilen P. Khomyakov was the project test pilot.

The Stage B schedule envisaged 204 test flights; however, 208 flights were actually made. The Air Force C-in-C endorsed the Stage B trials report on 8th December 1974, followed by the Navy C-in-C on 9th December; the Minister of Aircraft Industry had signed the document back on 26th November. The concluding part of the report read:

'1. The light VTOL attack aircraft created by the design bureau headed by A. S. Yakovlev has passed its State acceptance trials successfully and is recommended for service.

2. As regards some flight performance parameters the Yak-36M aircraft surpasses the British Harrier VTOL fighter-bomber (sic) *in a sortie involving vertical take-off.*

3. Yak-36M No. 03 shall be the pattern aircraft for the configuration recommended for production and service. (Sic; this is rather surprising, considering that the VM-3 still had the old narrow-track landing gear.)

4. The Yak-36M's ability to perform vertical take-offs from, and vertical landings on, a

Yak-36M f/n 0201 on the deck of SNS Kiev with the wings folded (note the AK-90F tiles on the deck). The wingtip fairings house puffers. The aircraft still has the narrow-track main gear and old air intake design.

ship's deck has been confirmed during operations from a stationary Type 1123 ship.

5. The aircraft has failed to meet the performance target stipulated by the Communist Party Central Committee/Council of Ministers directive in full.

6. The aircraft's strength characteristics basically meet the Air Force SOR. [...]

11. The Yak-36M can be mastered easily by proficient pilots with a supersonic fighter background who have taken special training on helicopters. [...]

15. The Yak-36Ms manufactured in accordance with the 1974 production plan are cleared for operation by first-line units and for use in the State acceptance trials of the Type 1143 ship, subject to the restrictions outlined in these presents.'

Some performance parameters of the R27V-300 main engine, as well as the operation of the air conditioning system and the hydraulic system, were assessed on the first prototype Yak-36M. The fourth prototype served for validating the SAU-36 automatic control system and testing the Kh-23 missile and its radio command guidance system.

As mentioned above, the Yak-36M's flight performance turned out to be somewhat lower than anticipated (and required by the CofM directive). For instance, the maximum speed was established as 1,210 km/h (752 mph) at sea level and 1,100 km/h (683 mph) at 11,000 m (36,090 ft) instead of the required 1,250 km/h (777 mph) and 1,400 km/h (870 mph) respectively. Effective range in 'clean' configuration when flying a VTOL mission profile at 200 m (660 ft) was 530 km (329 miles); with two Kh-23 missiles, the range in the same conditions was reduced to 430 km (267 miles). At 10,000 m (32,810 ft), the Yak-36M had a range of 860 km (534 miles) with two Kh-23 ASMs. The combat radius on a low-level VTOL mission with two UPK-23-250 cannon pods was 195 km (121 miles). The range fell almost 50% short of the required figure. Yet, the situation was not as hopeless as it may seem. By comparison, the Harrier GR.1 land-based version had a top speed of 1,050 km/h (652 mph) at sea level and its combat radius on a VTOL mission with two Martel ASMs, two rocket pods and a built-in cannon was a mere 92 km (57 miles).

During the tests the Yak-36M made short rolling take-offs with the flaps set 45° and a maximum take-off weight of 10,300 kg (22,710 lb). The following restrictions applied to the aircraft's flight envelope in squadron service: the angle of attack in a dive or in a climb was limited to 45°, the G load during vertical manoeuvres (recovery from a dive) was not to exceed 4 Gs, while the minimum control speed in forward flight was 450 km/h (279 mph) 'clean' or 500 km/h (310 mph) with external stores.

The military pointed out that the OKB had not verified the short rolling take-off mode which was specified in the SOR. They were also very thorough when it came to checking the restarting reliability of the powerplant at ambient temperatures right up to +32°C (89.6°F). The State acceptance trials showed that the R27V-300 lift/cruise engine started up reliably after an in-flight shutdown, spooling up from windmilling rpm to flight idle in 19-25 seconds. The RD36-35FV lift engines also behaved as they should throughout the trials; the time required for start-up was 7-14 seconds. Start-up reliability was 100% at the trials stage; however, when the Yak-36M entered squadron service, cases when the engines refused to start were unfortunately a fairly common occurrence.

The Yak-36M's powerplant had a few idiosyncrasies, and engine maintenance and

Top to bottom: The VM-4 and Yak-36M f/n 0201 on the deck of SNS *Kiev*; a pilot climbs into the cockpit of 0201, and the aircraft unfolds its wings before take-off. Above right: Yak-36M f/n 0201 tied down to the hangar deck. Right: The same machine on launch pad No. 4 with the lift engines running. Note the Soviet Navy flag and the white dielectric fin cap characteristic of production examples.

especially ground engine runs turned out to be quite difficult and complex procedures. For a ground run the aircraft had to be towed to a special hardstand with a heat-insulated surface and jacked up so that the landing gear oleos could be clamped; then the jacks were removed and the aircraft was tied down to the hardstand. Upon completion of the engine run the surface of the hardstand was doused with water to make it cool enough for walking on it, and the procedures were repeated in reverse order. What's more, during the first ten minutes after engine shutdown the ground crews had to wear respirators because the synthetic engine oil produced toxic fumes when heated.

The gunsight perched on top of the instrument panel impaired the pilot's field of view over the nose, especially if the angle of attack exceeded 6°. The rear view mirror on the canopy frame was of little use, allowing the pilot only to check if the lift engines' air intake scoop was open.

The State commission recommended the Yak-36M for service with the proviso that certain design changes be made. Specifically, the aircraft was to feature revised lift/cruise engine air intakes and the new wide-track landing gear; the view from the cockpit had to be improved and the instrument panel reconfigured. The military also demanded the installation of a Tester-UZL automatic flight data recorder (FDR), a GSh-23L built-in cannon and a new crew rescue system guaranteeing safe ejection throughout the flight envelope. The list of design flaws and malfunctions that had to be eliminated before the aircraft could be cleared for service consisted of 22 items; the list of defects to be eliminated within a timescale agreed by the MoD and MAP was much longer, comprising 274 items.

In September 1975 another aviation hardware display was arranged at Moscow's Central airfield named after Mikhail V. Frunze (better known as Moscow-Khodynka) for the benefit of the MoD top brass. Since the airfield is in the middle of the city, with heavily built-up areas all around, the aircraft were demonstrated only statically. The Yakovlev OKB put up the fourth prototype Yak-36M ('45 Yellow') – the pattern aircraft for series production. For added effect the entire range of compatible weapons was arrayed in front of the aircraft. Lt. Col.Yuriy A. Loonyov, the chief military representative assigned to the Yakovlev OKB, made the presentation for the guests. Having described the unique design features of the aircraft, he added, 'This aircraft is superior to the British Harrier VTOL aircraft as regards maximum speed at sea level and combat radius on a VTOL mission'.

When the report was finished and the visitors moved on to the next aircraft in the display line, one of the visiting marshals walked up to Loonyov and said, 'Don't give me that bulls**t, Lieutenant Colonel'. Yet, Loonyov was telling the truth, however improbable it may have sounded; the Harrier had a lot of advantages over the Soviet jet, yet the Yak-36M was indeed faster and 'longer-legged'.

It should be noted that not a single Yak-36M prototype was lost in the course of the manufacturer's flight tests and State acceptance trials. The Harrier was less lucky – three of the six P.1127 prototypes crashed in the course of the tests.

Upon completion of the trials programme the VM-3 was transferred to the Air Force Engineering Academy named after Nikolay Ye. Zhukovskiy (VVIA – *Voyenno-vozdooshnaya inzhenernaya akademiya*), which used it for developing jet exhaust deflectors. The VM-4 became a cutaway instructional airframe at the Moscow Aviation Institute.

On 4th April 1975 Mikhail S. Deksbakh suffered a landing accident in Yak-36M f/n 0302 at Saratov-Yoozhnyy. The extent of the fire damage to the aircraft is clearly visible; the machine was a total loss.

Yak-36M-O (Yak-36-O) Light Attack Aircraft (project)

Despite the steady progress of the Yak-36M project, OKB-115 was not yet about to give up on the idea of a single-engined VTOL aircraft that would not have to cart a set of lift engines about. By 20th December 1973, when the tests of the Yak-36M were well underway, Leon M. Shekhter's design team brought out another project designated Yak-36M-O (some documents referred to it as the Yak-36-O). The O suffix stood for *odnodvigatel'nyy* – single-engined. The Yak-36M-O was developed to meet the Air Force SOR dated 25th January 1969 – the one drawn up for the original Yak-36 *sans suffixe*.

According to the project, the two R27V-300 engines of the latter aircraft were to be replaced by a single *izdeliye* 55 turbojet uprated to 13,000 kgp (28,660 lbst) at full military power. This was a derivative of the R27-300 and the thrust increase was to be obtained by increasing the mass flow to 135 kg/sec (300 lb/sec) thanks to a modified compressor and turbine. The Yakovlev OKB had discussed the feasibility of developing such an engine with the Tumanskiy OKB (AMNTK Soyuz); the first *izdeliye* 55 engines were tentatively scheduled for delivery in the first quarter of 1973. Yet, OKB-115 was dissatisfied with the engine's thrust/weight ratio and specific fuel consumption; hence the *izdeliye* 55 was to be replaced with the R61V turbojet then under development. The single-engined project never materialised.

Yak-38 Production Attack Aircraft (Yak-36M, *izdeliye* VM; *izdeliye* 86)

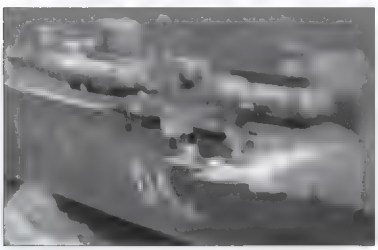
As mentioned earlier, upon completion of Stage A of the State acceptance trials the Yak-36M was cleared for production entry, and the Saratov aircraft factory No. 292 began manufacturing the jigs and tooling. It should be noted that the Saratov factory had a hand in the construction of the VM-2, VM-3 and VM-4, manufacturing the prototypes' fuselages which were delivered to Moscow for mating with the wings, tail surfaces and the rest. Also, the factory was contracted by the Black Sea Shipyard to build a mock-up of the Yak-36M equal in dimensions and weight to the real thing; this mock-up served for testing the deck lifts of the carrier SNS *Kiev* and verifying the parking and tie-down procedures on the flight deck and in the hangar.

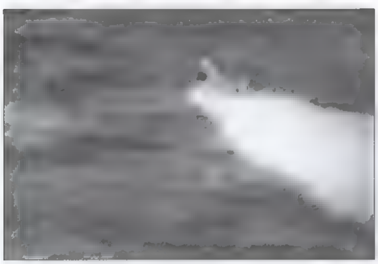
As the manufacturing drawings were issued, the design office of plant No. 292

(headed by L. F. Kirillov and project designer L. S. Krom) joined forces with OKB-115 to handle the multitude of technological issues arising on the way from paper to hardware. The plant's directors and chief engineers N. S. Denisov, A. I. Krivokhizhin and N. I. Dubrovin also invested a lot of effort into getting Yak-36M production started, as did factory test pilots A. M. Isayev, V. Abakoomov and V. Rabota, military test piots I. I. Shirochenko and A. M. Moskovtsev. Incidentally, Rabota (whose last name means 'work' in Russian) made the Guinness Book of Records by passing the aeronautical medical check without a hitch at the advanced age of 64; few pilots can boast such enviable health at this age. In 1995 he was awarded the Hero of Russia title in recognition of his services.

Yakovlev OKB designers and engineers G. A. Matveyev, S. N. Bogoroditskiy, A. Ya. Sviryukov *et al*. also provided a lot of valuable assistance to the Saratov aircraft factory. The Yak-36M's production entry was initially supervised by Stanislav G. Mordovin; later he was superseded by Viktor N. Pavlov. This was a time of intensive and fruitful cooperation between the Yakovlev OKB and the Saratov factory, its long-standing partner.

A special engine running hardstand and a VTOL/hovering pad were constructed at Saratov-Yoozhnyy (= Southern), the factory airfield of plant No. 292, for the purpose of conducting pre-delivery tests of production Yak-36Ms. Even more importantly, an SSM dynamometric test rig was also built; every single production example of the Yakovlev 'jump jet' was given the once-over on this rig.





Stills from a cine film capturing the crash of Yak-38 '45 Yellow' (c/n 7977863822377, f/n 0307) on 8th September 1980 in which Oleg G. Kononenko lost his life. The main engine nozzles failed to assume the correct position for a short take-off and the aircraft lost altitude, ditching in a cloud of spray.

Above: Another accident in Saratov on 4th March 1976 when Yak-36M c/n 7977861609443 (f/n 0903) kicked the pilot out of its own accord.
Right: The western military were lucky enough to photograph this in-flight fire of a Yak-38.

Unlike the prototypes, which had two-digit construction numbers, production Yak-36Ms (Yak-38s) have monstrous 13-digit construction numbers following the system introduced in 1973; for example, Yak-38 '29 Yellow' manufactured on 13th June 1977 is c/n 7977862706147. The explanation is as follows: 797 is a code for the Saratov aircraft factory obtained by replacing the twos in the factory number with sevens. 786 is the Yak-36M's in-house product code at the factory (*izdeliye* 86) with a 7 added at the front for some reason. 27 means that the aircraft was manufactured in the second quarter of 1977 (though this does not work in 100% of the cases – it has been seen that the actual manufacture date is later than what the c/n implies). The remaining five digits do not signify anything at all; the idea is to confuse would-be spies so that the c/n would not reveal how many aircraft have been built. The first two digits of these 'famous last five', as they are often called, change independently from the final three.

Adfditionally, production examples have four-digit *fuselage numbers* (f/ns); security is all very well but the manufacturer has to keep track of production, after all. Typically of Soviet aircraft, the f/n is not just a sequential line number (as in the case of Boeing and Douglas aircraft) but consists of the aircraft's number in the production batch followed by the batch number. (This 'reverse order' with the batch number after the number of the individual aircraft was typical of both the Yakovlev OKB and the Saratov factory, running contrary to the normal Soviet practice of putting the batch number first.) The aforementioned Yak-38 '29 Yellow' is f/n 0605 (the sixth machine out of ten in Batch 5).

The c/n is stencilled on a side wall of the nosewheel well; some aircraft had it stencilled in large digits on the rear fuselage. Also, the 'famous last five' are sometimes stencilled on the wing pylons and the sides of the lift engine intake scoop. Conversely, the f/n is found only in the aircraft's papers; the Yakovlev OKB uses the f/n in its records. However, some Yak-38s have it marked on air intake covers and the like to prevent these from being stolen. A production list is provided at the end of the book.

The first production single-seat Yak-36M (f/n 0101) was rolled out at Saratov-Yoozhnyy in May 1974. The first batch turned out to be unusually small, comprising three aircraft. The first machine was delivered to GNIKI VVS in Akhtoobinsk; the uncoded second aircraft (f/n 0201) went to the test facility of the Black Sea Shipyard in Nikolayev, while the third machine (f/n 0301) was assigned to LII. Batch 2 consisted of five aircraft (f/ns 0102 through 0502), and from Batch 3 onwards the number of aircraft per batch was increased to ten.

Production Yak-36Ms (Yak-38s) were powered by an R27V-300 (*izdeliye* 49) lift/cruise engine and two RD36-35FV (*izdeliye* 24) lift engines. The fifth production aircraft (c/n 797786…401035, f/n 0202) was set aside for static tests; however, it was not tested to

Yak-38 c/n 7977864401137 takes shape in the final assembly shop of the Saratov aircraft factory in 1974. The machine's f/n (0502) is temporarily painted on the fuselage.

destruction, later becoming a ground instructional airframe.

On 30th September 1974 Yakovlev OKB test pilot Mikhail S. Deksbakh and GNIKI VVS test pilot Vladilen P. Khomyakov began acceptance tests of the first production batch at the Saratov factory. Deksbakh made the first flight in Yak-36M f/n 0201 that same day.

The acceptance process was by no means trouble-free; systems and equipment failures kept cropping up, and several brand-new aircraft were lost for this reason. The first crash occurred on 4th April 1975 when Deksbakh was flying Yak-36M c/n 797786...401102 (f/n 0302). Taking off conventionally from Engels-2 AB (a heavy bomber base near Saratov), he was to make a vertical landing at Saratov-Yoozhnyy after performing the required set of manoeuvres. The sun was behind him as he approached the airfield; the warning lights in the cockpit were barely visible, and the pilot did not realise that the No. 2 lift engine had failed to start up. As Deksbakh vectored the thrust of the main engine and killed the forward speed, the aircraft's nose dipped and the machine entered a 17° dive from an altitude of 20 m (65 ft), not responding to control inputs. Seconds later, the Yak-36M struck the ground at 150 km/h (93 mph) and came apart, bursting into flames. The machine was a total wreck; Deksbakh sustained a spinal injury that kept him grounded for 18 months. The designers learned from this accident and introduced a two-needle gauge showing the turbine speed of the two lift engines separately.

On 4th March 1976 Khomyakov was due to perform the first 'full-profile' VTOL check-up flight from Saratov-Yoozhnyy in Yak-36M c/n 7977861602443 (f/n 0903). The weather was fine, with good visibility. Taking of vertically as planned, the pilot armed the SK-EM crew rescue system at an altitude of 8 m (26 ft); when the aircraft climbed to 20-25 m (65-80 ft), Khomyakov set the main engine nozzles to the intermediate position (25° from the vertical) and began the transition to forward flight, continuing the climb. Then, 49 seconds after lift-off, when cruise mode had been selected and the nozzles were vectoring through 60° from the vertical, the ejection seat fired spontaneously at 135 m (443 ft) as the aircraft accelerated through 375 km/h (233 mph). According to the FDR readouts, the machine's bank angle and angle of attack at the moment were 1° and +5°, while the pitch and roll rates were close to zero; in other words, definitely not the kind of situation to provoke an automatic ejection. Since the canopy jettison system did not come into play, the pilot was catapulted right through the canopy, parachuting to safety and landing on the ice of the frozen Volga River 2 km (1.24 miles) from the airfield.

Left to its own devices, the Yak-36M flew on, now controlled by the SAU-36 automatic control system which was still functioning in VTOL mode. Immediately after the ejection the No. 2 lift engine shut down and the delivery pump inside the No. 2 fuel tank stopped. The aircraft continued climbing and accelerating, the speed peaking at 650 km/h (404 mph) at an altitude of 1,000 m (3,280 ft). Next, the climb continued but the aircraft started losing speed, initiating a gentle turn to port. At 8,000 m (26,250 ft), when the indicated airspeed dropped to 225 km/h (139.8 mph), the aircraft stalled and flicked into a right spin; 2 minutes 8 seconds later it hit the ground 32 km (19.88 miles) from the airfield after making 18 turns of the spiral. The aircraft was partially destroyed by the impact and the post-crash fire; the entire flight had lasted 18 minutes 42 seconds. It did not take long to establish the cause of the uncommanded ejection, and the SK-EM system was modified accordingly to preclude such accidents.

LII test pilots Leonid D. Rybikov, Vladimir G. Gordiyenko, Vladislav I. Loychikov and Valeriy V. Nazaryan were called upon when it came to checking the Yak-36M's stability and handling at 500-1,100 km/h (310-683 mph) without external stores. The four pilots made 18 flights, all of them in CTOL mode.

On 23rd August 1978 Nazaryan had an emergency – the starboard mainwheel of his Yak-36M (f/n 0301) disintegrated on take-off. The pilot could not land the jet vertically because he had not yet taken the appropriate training; yet landing conventionally on the concrete runway with one mainwheel gone was also impossible. After weighing up all possible options the ground control ordered the pilot to eject after making sure that the aircraft would not drop on somebody's head. Nazaryan complied, heading for the Belo'omut area, but when he pulled the ejection handles he discovered that the canopy would not separate and hence the seat would not fire. The only option now was to jettison the canopy manually, extend the landing gear and attempt an off-field emergency landing in conventional mode. And this is exactly what he did. Luckily the ground of the clearing he chose for a landing strip was soggy, providing a strong braking effect, yet firm enough to prevent the aircraft from rolling over (remember that Yak-36M f/n 0301 had the old narrow-track landing gear). The pilot was unhurt.

In the course of production the Yak-36M was steadily improved and upgraded, the improvements being applied retroactively to existing machines. As mentioned earlier, the most important change was the introduction of the wide-track landing gear from the 11th production aircraft onwards. Concurrently the Yakovlev KYa-1M ejection seat was replaced with the Zvezda K-36VM seat (the VM suffix identified it as a version tailored for the Yak-36M, or *izdeliye* VM); with this seat the automatic ejection system was designated SK-EM. Longitudinal recirculation dams were added above and below the forward fuselage in the area of the lift engine bay. Lesser modifications included changes to the electric wiring, modified reaction control puffers, new electric controls for the lift engine nozzles and intake/exhaust doors, as well as for the ejection seat, and a revised SAU-36 automatic control system to enhance pitch stability.

Between 24th December 1976 and 27th June 1978 GNIKI VVS held check-up tests of an updated Yak-36M coded '46 Yellow' (c/n 7977864503511, f/n 0104) at the Akhtoobinsk facility. As compared to the VM-3 prototype designated as the *etalon* (pattern aircraft) for 1978 production, this aircraft featured a whole raft of changes:

North Fleet Air Arm Yak-38s at Severomorsk-3 AB interspersed with APA-50 ground power units based on the ZiL-131 6x6 army lorry.

- the fuselage structure was modified to incorporate integrated wing spars;
- the detachable wings gave place to permanently installed ones;
- the fin tip was recontoured;
- the wide-track landing gear was fitted;
- the cockpit canopy had an enlarged transparency;
- the instrument panel and lateral cockpit consoles were reshaped, and the flight instruments and switches were rearranged;
- the lift engines had fixed-area (non-adjustable) nozzles;
- changes were made to the design of the main engine's air intakes (boundary layer splitter plates were added);
- the hydraulic actuators now used jet fuel as the working fluid instead of AMG-10 oil-type hydraulic fluid;
- the navigation/attack suite now had a micro-modular architecture with line replaceable units;
- the area of the boundary layer splitter plates on the lift/cruise engine's air intakes was reduced;
- the KYa-1M ejection seat gave place to the K-36VM ejection seat;
- the SARPP-40 flight data recorder was replaced with the Tester-UZL FDR;
- the fire suppression system was deleted;
- the steerable nose gear unit was replaced with a castoring one.

Almost all of these changes eventually found their way into production.

On 11th August 1976 the Communist Party Central Committee and the Council of Ministers issued directive No. 644-210 officially including the Yak-36M shipboard attack aircraft into the Naval Aviation inventory. From this moment on the aircraft bore a new service designation, Yak-38; the Saratov aircraft factory switched to the new designation on 6th October 1976.

In spite of the many design changes, which generally tend to add to an aircraft's empty weight, the Saratov factory managed to keep the Yak-38's weight within the specified limits.

Between 1973 and 1983 the factory produced 143 single-seat Yak-36Ms and Yak-38s. The production rate peaked at 21 aircraft in 1981. The early production examples had a designated service life of only 400 flight hours and a guaranteed service life until the first major overhaul of 100 hours or two years. By the end of 1988, when the Yak-38's operational career was drawing to a close, the designated service life had increased to 500 hours and 2,400 cycles. The Yak-38 was designed to last 16 years; the time between overhauls (TBO) was 200 hours and 800 cycles over a six-year period.

In 1974 the second production Yak-36M (f/n 0201) passed State acceptance trials in accordance with the same Stage B programme as the VM-3 prototype. A. F. Travin was the engineer in charge and V. V. Korolyov was the aircraft's mechanic.

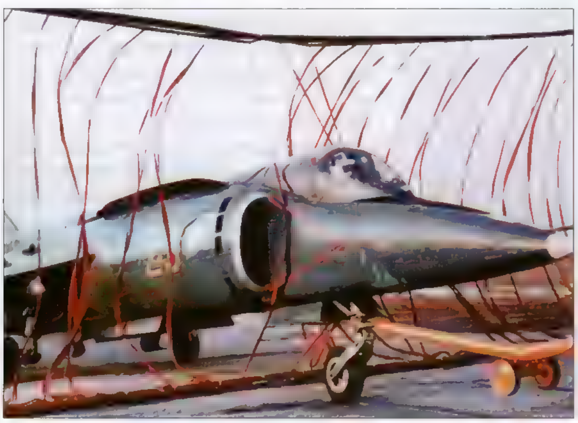
Along with the fourth prototype (VM-4, '45 Yellow') the same aircraft participated in the seagoing trials of the new aircraft carrier SNS *Kiev*. On 18th May 1975 the second production Yak-36M flown by LII test pilot Oleg G. Kononenko gained the distinction of being the first jet to land on the *Kiev*; it was followed shortly afterwards by the VM-4 with Vladilen P. Khomyakov at the controls. This took place off Bel'bek, not far from Sevastopol'.

Oleg G. Kononenko sits in the cockpit of his Yak-38. The windshield frame carried one of the instruments.

Between 18th May and 30th June 1975 the Yak-36M was subjected to extensive carrier compatibility trials – both in flight, on the deck and in the hangar. Kononenko and Khomyakov made a total of 17 flights with the ship both at anchor and in motion; in the latter case the resulting slipstream velocity reached 18 m/sec (36 kts) and the operations were complicated by the ship's rolling.

On 20th May 1975 the Soviet Minister of Defence Marshal Andrey A. Grechko and the Soviet Navy C-in-C Fleet Adm. Sergey G. Gorshkov arrived aboard the SNS *Kiev* to check up on the progress of the trials. Kononenko did his best, demonstrating the capabilities of the 'jump jet' in a brief demo flight from the ship's deck.

State acceptance trials of the SNS *Kiev* took place between 7th August and 16th September 1975. Within this time frame the two aircraft involved made 31 flights, including ten 'full-profile' VTOL flights and 21 hovers. Kononenko and Khomyakov performed take-offs with various external stores options from the carrier's six launch pads. The flying part of the programme was completed on 12th September; the following day the VM-4 prototype



This production Yak-38 coded '23 Yellow' (possibly f/n 0703) was used for testing the crash barrier developed for Kiev class aircraft carriers. Note the dark green undersurfaces characteristic of production examples.

and Yak-36M f/n 0201 departed for Kirovskoye AB and Bagerovo AB respectively. During the manufacturers's tests and State acceptance trials of the SNS Kiev the Yak-36Ms accomplished a total 48 flights from the ship, including 16 VTOL flights. Deputy General Designer Kerim B.Bekirbayev and Col. O. A. Voronenko (representing GNIKI VVS) supervised the flight test programme. The project engineers were V. I. Latyshev and A. B. Zvyagintsev representing OKB-115, Lt. Col. G. M. Marakulin (he superseded Andronov in the spring of 1975) and Lt. Col. I. D. Starkov representing GNIKI VVS; mechanics A. I. Ivanov and Ye. N. Yermolayev were assigned to the fourth prototype and the production machine respectively for the duration. These flights concluded the manufacturers's seagoing tests and State acceptance trials of the carrier.

Originally the third prototype Yak-36M ('55 Yellow') was supposed to participate in the trials as well, but the plan was foiled when one channel of the SAU-36 failed en route. Test pilot Oleg G. Kononenko took no chances and made a precautionary landing at Saki in conventional mode.

Next, the pilots began polishing the technique of landing on a moving ship. Additionally, the GNIKI VVS test programme included assessing the possibility of operating the aircraft (that is, flight operations and maintenance) when the ship heaved and rolled in rough seas. As no stormy conditions were present on the Black Sea during the tests, the swells were simulated by means of the ship's roll stabilisers, which were used to do the opposite of their normal function and induce oscillations instead of damping them. The results of the tests proved positive and the Yak-36M was recommended for inclusion into the *Kiev*'s weapons system as the aviation component. In December 1975 SNS *Kiev* was commissioned by the Navy and received its carrier wing composed of production Yak-38s.

Top: '05 Yellow', the Yak-36MU trainer prototype (VMU-1). Note the horizontally cropped fin.
Left and above: Sharks'R'Us. The VMU-1 looks rather strange from these angles. Note the forward reaction control puffer and the narrow wheel track.

Many of the initial-production Yak-36Ms underwent special tests in the course of 1975-76. The cockpit instrumentation, gunsight and other systems and equipment were verified, and various armament options were also tested. Thus, the second production machine served as a 'dogship' for debugging the ASP-17BMTs computing gunsight in 1976, while the eighth machine of Batch 3 (Yak-36M '21 Yellow', c/n 797786...02409, f/n 0803) was earmarked for testing another gunsight – the ASP-PFD-21 borrowed from the MiG-21PF interceptor. Three Batch 2 machines – c/n unknown (f/n 0102), c/n 797786...401035 (f/n 0202, coded '11 Yellow') and c/n 797786...401103 (f/n 0402) – were deployed at Novofyodorovka AB, Saki, in November 1975; they served for conversion training of pilots that would serve with the soon-to-be-established shipboard attack air regiment. The skilled pilot Feoktist P. Matkovsky had been appointed the unit's CO; earlier, he had flown both shore-based fighters and helicopters in the AVMF. In the summer of 1976 the first squadron of Yak-36Ms was formed and took up residence on SNS *Kiev*.

In preparing the production machines for service in the open seas OKB-115, together with the Naval Aviation command and the shipbuilders, had to tackle many problems associated with shipboard operations. It was necessary to accommodate the aircraft ammunition, jet fuel, data recording and deciphering equipment (for deciphering the FDR readouts), storage facilities, etc. aboard the carrier, to provide refuelling and electric power supply for the aircraft, to check the Yak-36M's avionics and equipment (especially the weapons control system) for electromagnetic compatibility with the carrier, given the strong electromagnetic fields created by the ship's radar and other electronic systems. To handle all these specific issues the Yakovlev OKB had organised a shipboard operations team back in late 1972; it was headed by V. P. Vlasov, the Yak-36M's deputy project chief. The OKB invited former employees of the Central Directorate of Shipbuilding and former Navy HQ officers transferred to the reserve to join the team.

The production items of aircraft ammunition and removable weapons carried by the Yak-36M were developed to meet Air Force operational requirements, which had been drawn up with ordinary airfields in mind and did not take into account the peculiarities of shipboard operations. The need arose to carry out additional tests of weapons and ammunition with the purpose of 'estimating their operational reliability during operations aboard a Type 1143 ship'. In 1976 the Yak-36M underwent special tests at the Bagerovo target range and on the SNS *Kiev*

'to verify the operational safety of the aircraft and its weapons in the conditions of electromagnetic interference created by the ship's radars'. The first prototype Yak-36M and a production example (f/n 0308) participated. In these tests, which went successfully; the test report was endorsed by Vice-Adm. Ye. I. Voloboovev, who chaired the State commission clearing SNS Kiev for Navy service.

In late December 1976 the GNIKI VVS test personnel in Akhtoobinsk started preparations for night flight training; as already mentioned, by then the aircraft had already received the new designation Yak-38. To this end the contour of the runway on the flight deck of SNS *Kiev* was marked in luminescent paint on a special pavement for VTOL aircraft near the main runway at Vladimirovka AB. Four runway lights and a flashing beacon were installed, and the runway threshold was designated by a triangle pattern. The purpose of tests was to estimate the external lighting equipment of the Yak-38 and the lighting of the ship's launch pads.

Vladilen P. Khomyakov performed the tests; he started off by making several flights in a Mi-8 helicopter above the 'carrier deck' on 8th February 1977, then flew the second production Yak-38 at night in CTOL mode from the 'carrier deck' to assess the lighting equipment. (A. F. Travin was the engineer in charge, and V. V. Korolyov was again the mechanic.) After that, Khomyakov made a few hovers above the pad; on 28th March he performed a 'full-profile' VTOL flight at night, thereby completing that test programme. The chief of GNIKI VVS endorsed the 'Report on the results of special flight tests for the purpose of determining the possibility and special features of night flights' on 20th May 1977.

In October 1977 the production Yak-38 was demonstrated to members of the government for the first time at Kubinka AB. AVMF instructor pilots V. I. Kuchooyev, V. F. Saranin and N. N. Novichkov were supposed to make demo flights, but they did not have a chance to do so. The practice flights before the show went successfully, but on the day of the show nasty weather ruined the flying display and the aircraft were displayed only statically.

The programme reached a major milestone in December 1977 when Col. Vladilen P. Khomyakov made the first night landing on SNS *Kiev* in a Yak-38 near Severomorsk on the North Sea, assessing the lighting equipment of the ship. Then he executed five hovers at wind speeds of 5-15 m/sec (10-30 kts) and two 'full-profile' VTOL flights. He also explored the possibility of hovering at night over a cruising ship (in the Barents Sea), with the ship pitching and rolling at 3º, 5º and 6º, and also over a stationary in Kola Bay.

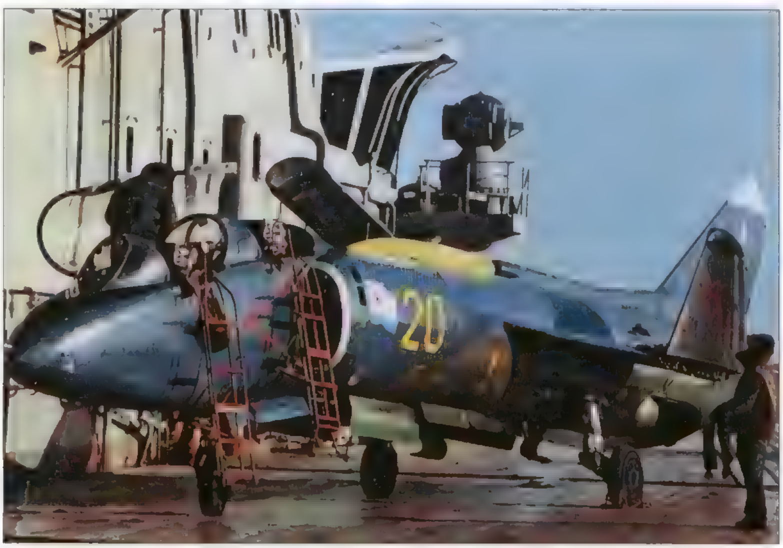
(Note: As noted earlier, originally the *Kiev* had been officially referred to as an ASW cruiser (PKR – *protivolodochnyy kreyser*). In 1977 the Soviet Navy changed the classification of its combat and support ships, and the aircraft carriers were henceforth officially called 'heavy aircraft-carrying cruisers' (TAKR – *tyazholyy avianesooshchiy kreyser*). The term was coined to find a way around the Montreux Convention of 1936 prohibiting the passage of aircraft carriers through the straits of Bosporus and Dardanelles. Since the Soviet carriers were all built at the Black Sea Shipyard, calling them by their proper name would mean they would be locked in the Black Sea, which of course was totally unacceptable. Obviously the Soviet Union did not even dream it would operate aircraft carriers one day when it signed the convention! Another reason for the odd name was that most of the Soviet carriers were armed with missiles into the bargain.)

The aircraft used in these tests was Yak-38 '19 Yellow' (c/n 797786…502273?, f/n 0503). All in all, the machine made 18 flights from the Nos. 4 and 5 launch pads. Khomyakov gave the following assessment: 'The lighting equipment of the production Yak-38 and the regular lighting equipment of the Type 1143 ship make it possible to perform [night] flights, providing that the PKP-72M artificial horizon is replaced with a flight director'. On 14th December 1977 Khomyakov performed similar tests of the Yak-36MU two-seat trainer (see below), assessing the lighting equipment and carrying out VTOL flights at night.

In 1977 the design team responsible for the Yak-38's development received the prestigious State Prize of the USSR. The laureates included General Designer Aleksandr S. Yakovlev, Stanislav G. Mordovin, Kerim B. Bekirbayev, Aleksandr A. Levinskikh, Klavdiya S. Kil'disheva, Leon M. Shekhter and B. B. Vorob'yov. By decree of the Presidium of the USSR Supreme Soviet many employees of OKB-115 and its 'subcontractors' received state awards and medals.

The AVMF's service pilots had already mastered the Yak-38, and the *Kiev* class air-

The Yak-36MU prototype makes its first vertical take-off. The trainer had an oddly banana-shaped fuselage.



A production Yak-38U aboard a Kiev-class aircraft carrier. The machine features additional dorsal and ventral recirculation dams; the dorsal ones are unpainted, suggesting a mid-life update.

Above: A production Yak-38U coded '06 Yellow' (possibly f/n 0302) adorned with a Soviet Navy flag.

'07 Yellow', another in-service Yak-38U, shows the wide-track landing gear and the raked fin tip of the production version.

craft carriers equipped with the type were in active service; yet the tests of production Yak-38s continued, with no end in sight. The reason was that the customer kept thinking up new requirements, while the designers were getting new ideas about improving the aircraft. Also, new equipment and armament kept appearing.

Operational experience with the Yak-38 on the ships had shown the expediency of revising the approach procedure for a vertical landing, so that the lift engines could be started in a turn, not only in straight-line flight. This made it possible to save fuel when commencing the landing pattern on a heading reciprocal to the final approach, and to start the lift-jets when 3-4 km (1.86-2.5 miles) out instead of the usual 6-8 km (3.72-5 miles) – that is, within visual range of the ship in adverse weather. Special flight tests were undertaken at Saki with a production Yak-38 '28 Yellow' (c/n 797786...605681, f/n 0604) from 9th October to 18th November 1978 to assess flight safety and the reliability of the RD36-35FV lift engines' start-up during banked turns. Project test pilot Vladilen P. Khomyakov made 14 flights totalling 7 hours 30 minutes under this programme; V. P. Litvin was the engineer in charge.

It turned out that the lift engines started reliably during turns with bank angles up to 80°. The tests were conducted in level flight without sideslip at altitudes of 200-500 m (660-1,640 ft) and indicated airspeeds of 400-460 km/h (248-286 mph). The conclusion drawn from the tests was: *'... Starting the lift engines during banked turns within the checked altitude and speed range does not affect the stability and flight safety of the Yak-38'*.

On 8th September 1980 a production Yak-38, '45 Yellow' (c/n 7977863822377, f/n 0307). crashed in the South China Sea, killing LII test pilot Oleg G. Kononenko. This was a sore blow, since Kononenko's contribution to the tests of the first Soviet shipboard VTOL jet cannot be overestimated. When making a short rolling take-off from the carrier SNS *Minsk* the machine suffered a malfunction of the main engine nozzle actuator; the nozzles failed to assume the correct position (25° to the vertical), remaining at 60° to the vertical. After clearing the end of the angled deck the aircraft 'fell through', losing altitude steadily; after travelling 150-200 m (490-660 ft) above the water in a fountain of spray the machine ditched, turning 180° to face the ship, and remained afloat for one minute before going under. Kononenko had ample time for ejection, and in fact he was ordered to eject by the ATC shift supervisor who saw that the take-off had 'come unstuck'. Yet the pilot ignored the order and stayed with the aircraft, trying to the last to gain altitude and save the machine.

Between 1974 and 1980 the Soviet Navy's aircraft fleet included 115 Yak-38s. 16 of these were lost in accidents, including four fatal ones. However, before drawing a conclusion about the reliability and flight safety of the Soviet shipboard attack aircraft it makes sense to compare it with the Harrier. 241 Harriers were delivered between 1969 and 1980. Within this time frame there were 83 accidents; 57 machines were total hull losses and 25 pilots were killed. Such an attrition rate comes as no surprise for a VTOL aircraft.

In August-September 1983 LII and OKB-115 made a joint estimation of the airflow parameters on the third *Kiev* class carrier, SNS *Novorossiysk*, which, as already noted, incorporated design changes. They concluded that the Yak-38 could safely perform short rolling take-offs from the carrier at take-off weights of 9,380-10,450 kg (20,680-23,040 lb). The tests took place in the Arctic and Atlantic Oceans, involving ten flights. The five production aircraft participating in the tests were coded '46 Yellow' (c/n 797786406..., f/n 0311), '73 Yellow' (c/n 797786...286815), '74 Yellow' (c/n 797786...286840), '75 Yellow' (c/n 797786...290847) and '86 Yellow' (c/n 797786...97565). They were flown by project test pilot Col. Viktor V. Vasenkov (GNIKI VVS), with N. M. Kozenchuk as engineer in charge. The concluding part of the report on the tests of production Yak-38s in short take-off/vertical landing (STOVL) mode said, *'...the stability and control characteristics of the Yak-38 enable short rolling take-offs from the modified flight deck of the heavy aircraft-carrying cruiser Novorossiysk. The aircraft's powerplant runs steadily during short take-offs from the ship'*.

Meanwhile, at Saki, not only conversion training of pilots was in progress but production Yak-38s were also used in a number of special test programmes. Thus, in keeping with orders from the Navy C-in-C, in September 1983 the pilots of a first-line AVMF unit made practice landings on a commercial vessel – the 'ro-ro' (roll-on/roll-off) freighter M/V *Agostinho Neto*. This was the first time in the USSR when military aircraft landed on a civil ship. Of course, the ship was suitably equipped with a landing platform to protect the deck from the hot jet exhaust.

Landing on the commercial freighter was risky business. Unlike the flight deck of the carrier, which was virtually free from obstructions, the top deck of the freighter featured ventilation risers along the sides. Their superstructures were 5.3 m (17 ft $4\frac{21}{32}$ in) long, 2.3

m (7 ft 6$^{35}/_{64}$ in) wide and 3.0 m (9 ft 10$^{7}/_{64}$ in) high. This restricted the landing pad for the: 'jump jets' to 24 x 18 m (78 ft 8$^{7}/_{8}$ in x 59 ft 0 in), which was quite small. Landing approaches were carried out on diagonal courses from various headings (because the ship's superstructure got in the way), and the pilots had to land with pinpoint precision. Besides, the risers belched warm air, creating turbulence that made the landing even more complicated. Hence for safety's sake the air outlets in the risers were temporarily blanked off by welding steel sheets over them.

The first landing of a Yak-38M on M/V *Agostinho Neto* took place on 14th September, the aircraft being piloted by Yuriy N. Kozlov. Later, Col. G. L. Kovalyov, Lt. Col. V. I. Kuchooyev and Lt. Col. V. N. Pogorelov also landed on the freighter. By 29th September 20 take-offs and landings had been made.

The OKB and the Saratov aircraft factory introduced a steady stream of design changes in order to improve the type's operational reliability. About 160 modification bulletins were issued for the airframe alone, concerning heat insulation of structural members and equipment items, strengthening and redesign of the recirculation dams, lift engine bay doors, weapons pylons, main and lift engine air intakes, powerplant controls etc. These changes were to be introduced on the production line and effected on in-service aircraft. All this gave a tremendous boost of operational reliability; the mean time between failures (MTBF) in flight was tripled as compared to the Yak-38's service introduction days. The number of flights per one in-flight failure increased 20-fold. The mean time between failures revealed in flight and on the ground increased 2.5 times.

It should be noted that the Yak-38 ranked first among Soviet warplanes as far as the number of production aircraft involved in flight tests and special test programmes. Thus, by February 1981 Yak-38 '07 Yellow' (f/n 0103) had executed 473 flight cycles, the first production example ('03 Yellow', f/n 0101) performed 382 cycles, Yak-38 '22 Yellow' (c/n 797786...502477, f/n 1003) made 276 cycles and an example coded '51 Yellow' performed 255 take-offs and landings. A total of 74 test flights were performed on SNS *Kiev* in 1975; in 1976 there were no flights, but 45 test flights followed in 1977 and another 20 flights in 1978. On the sister ship SNS *Minsk*, 47 test flights were made in 1979 and 143 test flights in 1980.

This sequence shows the crash of Yak-38U '09 Yellow' (c/n 7977761813264, f/n 0303) on take-off from SNS *Minsk* on 27th December 1979. The main engine nozzles failed to rotate to 25° from the vertical for a short take-off; the aircraft pitched up immediately and was in the drink. Pilots Mikhail S. Deksbakh and Oleg G. Kononenko ejected safely, Deksbakh landing right on the carrier's deck!

Above: This Yak-38U coded '07 Yellow' was operated by LII and used for test and development work. Note the non-standard nose pitot.

Special tests to determine the Yak-38's maximum take-off weight in extreme conditions in VTOL mode were held aboard SNS *Minsk* and SNS *Novorossiysk*, taking place the carriers' during tours of duty in the Arctic, Atlantic, Indian and Pacific Oceans. The test programme included 36 flights performed between 4th November 1982 and 14th May 1984. The four aircraft involved in this programme were the aforementioned Yak-38s '46 Yellow' (f/n 0311), '75 Yellow' (c/n 797786...290847) and '86 Yellow' (c/n 797786...97565) plus Yak-38 '58 Yellow' (the c/n was reported as ending 6657 – that is, 797786...176657?).

The tests took place at ambient temperatures from –8°C (+17.6°F) to +30°C (86°F), varying atmospheric pressure and slipstream speeds above the deck varying from 2 to 15 m/sec (4-30 kts). It came to light that in a tropical climate the thrust losses were sometimes so great that the Yak-38 simply could not become airborne. The take-off weight varied from 8800 to 10130 kg (19,400-22,330 lb).

Again, GNIKI VVS test pilot Col. Viktor V. Vasenkov did the flying, with N. M. Kozenchuk as engineer in charge. The concluding part of the test report said that the maximum take-off weight of the Yak-38 with uprated engines in a vertical take-off from the ship in extreme conditions (at +30°C and an atmospheric pressure of 760 mm Hg) amounted to 9,100 kg (20,060 lb); the maximum landing weight in a vertical landing in these conditions was 8,800 kg (19,400 lb).

A few time-expired production Yak-38s were donated to museums, relegated to aviation educational institutions as instructional airframes or preserved as gate guards. For example, the second production Yak-36M (f/n 0201) took up residence in the Yakovlev OKB museum on 21st January 1980 (it sports a non-standard grey colour scheme). Yak-38 '14 Yellow' (c/n 7977864401137, f/n 0205) was preserved in the Soviet Air Force Museum in Monino south of Moscow (now the Central Russian Air Force Museum), while sister ship '60 Yellow' (c/n 7977864060699, f/n 1010) resided in the open-air museum at Moscow-Khodynka (now defunct, unfortunately). By the summer of 1980 Yak-38 f/n 0403 was transferred to an aviation engineering school in Riga after the termination of special tests to be used as a teaching aid.

The single-seat Yak-36M (Yak-38) received the NATO reporting name *Forger*. This was later amended to *Forger-A* when the existence of the trainer version came to light.

Looking rather dilapidated, Yak-38U '01 Yellow' was one of many *Forgers* stored at Saki. Note the unusual 'Danger, air intake' markings.

This example (c/n 7977764505037) preserved in the Lugansk aviation museum in the Ukraine, may be the same aircraft following restoration. Again, the intake warning markings are non-standard.

Yak-36MU Trainer Prototype (*izdeliye* VMU-1)

A dual-control trainer version of the Yak-36M was required for training aircrews in the 'jump jet's' piloting techniques, in particular vertical take-offs and landings. Such an aircraft was envisaged at an early stage – the Communist Party Central Committee/Council of Ministers No. 1166-413 of 27th December 1967 provided for the development of a conversion trainer. Yet, the SOR for the trainer variant was not endorsed by the Soviet Air Force Deputy C-in-C (Armament) until 4th March 1971; the SOR was duly coordinated with the commander of the AVMF. Apparently the manufacturer's flight tests of the Yak-36M had already given the customer confidence in the aircraft. The trainer received the provisional service designation Yak-36MU and the in-house product code *izdeliye* VMU, the U suffix standing for *oochebnyy* [*samolyot*] – trainer.

For starters, MMZ No. 115 (the prototype construction facility of OKB-115) built a mock-up of the trainer's forward fuselage with cockpit equipment equivalent to Stage A of the single-seater's State acceptance trials. The Air Force/Navy mock-up review commission approved it in February 1972.

The aircraft was intended for training aircrews in VTOL procedures, hovering and transition to and from forward flight. Being intended for carrier operations, the Yak-36M attack aircraft was very compact, with the systems and equipment packed into a very small space, and accommodating a second cock-

pit for the instructor affording him a good field of view was no easy task. The designers decided to extend the fuselage nose and place the trainee ahead of the instructor; the forward fuselage was slightly drooped to give the back-seater a measure of forward view. The tandem cockpits were enclosed by a common canopy with individual hinged portions opening to starboard and a fixed portion in between. The longer nose made it necessary to extend the rear fuselage accordingly, increasing the moment arm of the horizontal tail. As a result, the aircraft turned out to be disproportionately long with respect to the wing span; moreover, it looked uncannily like a banana.

The issue of crew rescue in an emergency also had to be resolved. For the first time in world aircraft practice, the Yak-36MU's crew rescue system provided simultaneous enforced ejection of both crewmembers in VTOL mode if the aircraft's attitude became unsafe.The ejections were sequenced with a 0.6-second delay during manual ejection and the seats were designed to follow diverging trajectories in order to prevent a collision.

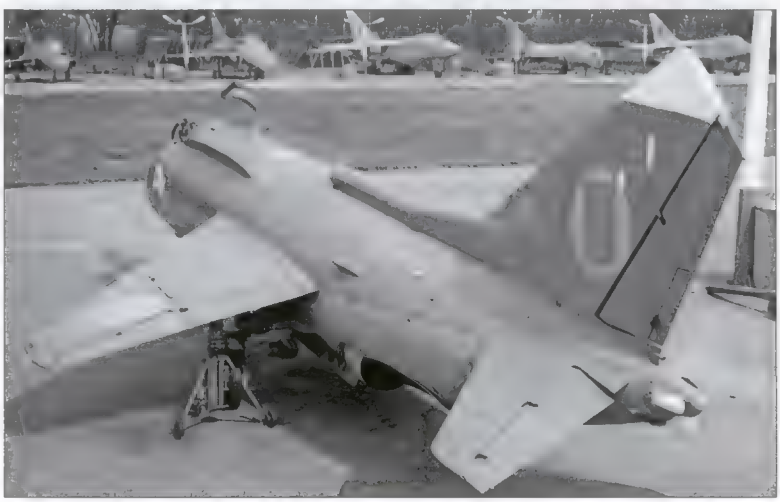
On 23rd March 1973 MMZ No. 115 completed construction of the first trainer prototype (known as *izdeliye* VMU-1) bearing the tactical code '05 Yellow'. Stage A of the Yak-36MU's joint State acceptance trials began on 23rd March 1973 in Zhukovskiy. On 17th August that year OKB test pilot Mikhail S. Deksbakh performed the trainer's maiden flight in CTOL mode, with test pilot Yuriy I. Mitikov flying chase in a Yak-28. Next, a series of CTOL flights was made to explore the flight envelope and calibrate the pitot. G. A. Fedotov was the Yak-36MU's project engineer and V. F. Sobolevsky was the mechanic.

Next, the VMU-1 was transferred to GNIKI VVS, undergoing tests in Akhtoobinsk from 25th September 1973 to 31st July 1974. A month after the transfer, on 25th October, Deksbakh performed the first two free hovers in the Yak-36MU prototype. In November-December he performed more hovers, flying the aircraft from the instructor's seat; then, in February 1974, a series of flights began involving a conventional take-off followed by start-up of the lift engines and deceleration to the hover. On 22nd March 1974, a speed of 900 km/h (559 mph) at 5,000 m (16,400 ft) was attained; four says later Deksbakh executed a 'half-profile' mission, taking off vertically and accelerating to 900 km/h before making a conventional landing. Finally, on 30th March, the pilot performed the first 'full-profile' VTOL flight in the trainer.

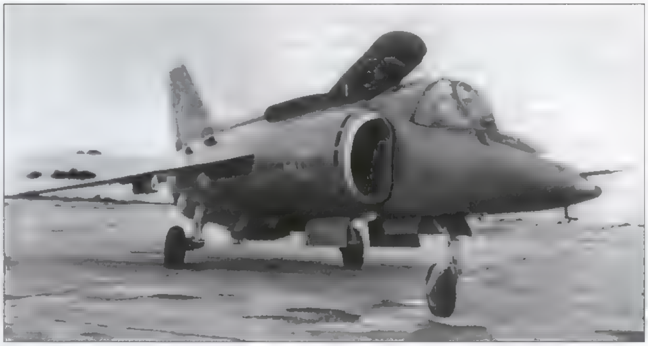
All in all, Stage A of the State acceptance trials involved 90 sorties – both test flights under the programme and training flights. At the end of Stage A the two-seater received a positive appraisal; yet, the State commission recommended that different avionics and equipment be fitted before production of the Yak-36MU could begin, and found it expedient to continue the trials on a production machine.

In April-September 1977 the Yak-36MU prototype (VMU-1) underwent Stage B carrier trials aboard the SNS *Kiev* (more of this later). The results proved encouraging and the trainer was recommended for service. Later

Above: After ending its flying career the VMU-1 became a gate guard in Saki.



This unidentified Yak-38U served as a teaching aid at a Ukrainian Air Force technical school and was adorned retroactively with UAF insignia.



Top, top right and above: Yak-38 '46 Yellow' (c/n 7977864503511, f/n 0104) in standard dark blue/dark green colours was the first example to be tested with the VSPU-36 conformal cannon pod.
Right: Close-up of the VSPU-36. The pod is located well aft.

the prototype was used for conversion training of service pilots – first by GNIKI VVS in Akhtoobinsk, then by the AFMF's shipboard aviation aircrew training centre in Saki. It subsequently became a gate guard on a concrete plinth at Novofyodorovka AB, Saki, after running out of service life.

Yak-38U (Yak-36MU) Production Trainer (*izdeliye* VMU; *izdeliye* 76?)

The manufacturing documents for launching production of *izdeliye* VMU were transferred to the Saratov aircraft factory right on schedule in November 1974. The first production Yak-36MU trainer was completed in 1975. Yak-36MU construction numbers followed the same system but the second group of digits was 776, suggesting the product code was *izdeliye* 76, and the trainer had a separate fuselage number sequence; the f/ns were sometimes suffixed U. Batch 1 consisted of only two machines (f/ns 0101 and 0201), Batch 2 had three (f/ns 0102 through 0302); subsequent batches comprised five aircraft each – for example, the 18th production Yak-36MU was f/n 0305.

The second production aircraft (c/n 7977764505037?, f/n 0201) was delivered to GNIKI VVS. The fourth production machine (f/n 0202), like the single-seater with the same fuselage number, was a static test article.

GNIKI VVS undertook tests of the first production trainer to check its stability and handing after the two-seater had been modified to eliminate the shortcomings noted during the prototype's State acceptance trials. Col. Vladilen P. Khomyakov was project test pilot, with Col. Viktor V. Vasenkov as his back-up; V. D. Litvinov was the engineer in charge.

Yak-36MU f/n 0101 differed from the prototype in the following ways:

- the crew rescue system featured K-36VMU ejection seats;
- the main engine air intakes were modified;
- the wide-track landing gear was fitted;
- the SAU-36 automatic control system using semiconductor electronic components was installed;
- the instrument panels in both cockpits were reconfigured;

This grey-painted Yak-38, likewise coded '46 Yellow' and fitted with a VSPU-36, is a different machine (c/n 797786...174635, f/n 0312). Note the RR8311-100 air sampling pod for radiation reconnaissance.

• the vertical tail was redesigned and its area was reduced by 0.1 m² (1.08 sq ft);

• the aircraft's weights and CG range were changed.

Since the aircraft did not carry a test and recording equipment suite, the estimation of its performance, handling and systems was based on the pilots' impressions and reports. True, the records of the standard Tester-UZL FDR were also used to check the flight modes attained during the tests.

The trials report was endorsed by the chief of GNIKI VVS on 20th April 1976. This document contained the following conclusion:

'1. According to the pilot's estimates, the production Yak-36U (sic) *trainer No. 0101 is virtually identical to the Yak-36U trainer prototype No. 05* (that is, '05 Yellow' – *Auth.*) *tested at Stage A of the joint State acceptance trials as far as the stability and control characteristics in the checked range of altitudes, speeds and G loads are concerned.*

2. The design changes implemented on the first production aircraft in order to rectify the faults enumerated in List 1 of the preliminary report on the Yak-36U prototype have basically improved the aircraft's operational standards and can be recommended for introduction on the assembly line. However, some of the the modifications made in accordance with List 1 [...] are insufficiently effective. The faults specified in the respective items [of List 1] are again included in the List [of deficiencies] contained herein and shall be eliminated prior to Stage B of the Yak-36U's State acceptance trials.

3. The aircraft can be recommended for operation first-line units of the Air Force and the Naval Aviation, subject to the following temporary restrictions (until the termination of Stage B):

• the maximum indicated airspeed at 5,000 m [16,400 ft] 750 km/h [466 mph];

• operational G limit 3.0;

• take-off and landing in conventional mode are possible in crosswinds at 90° to the direction of flight of no more than 7 m/sec [14 kts];

• flights shall be performed by a full crew of two.'

The third production Yak-36MU trainer (c/n 7977763611071, f/n 0102) was submitted for Stage B at GNIKI VVS on 27th December 1976. Trials of this aircraft and the prototype began on 8th April 1977, lasting until 12th September. Vladilen P. Khomyakov, Viktor V. Vasenkov and V. Golub did the flying, while N. M. Kozenchuk was the engineer in charge. The two trainers made 40 flights between them, 35 of these being credited for the trials. In all, the State acceptance trials of the Yak-36MU included 130 flights. The trainer was formally included into the inventory by order No. 0196 signed by the Minister of Defence on 15th November 1978; however, as early as 6th October 1976 the two-seater received the new service designation Yak-38U.

Series production of the trainer proceeded in parallel with that of the single-seat Yak-38 at a rate of four to five machines a year. Between 1976 and 1985 the Saratov aircraft factory completed 38 of the trainers; the last one was f/n 0308. OKB-918 (NPP Zvezda) headed by General Designer Guy I. Severin developed a special version of the K-36 ejection seat tailored for the Yak-38U – the K-36VMU.

On 27th December 1979 Yak-38U '09 Yellow' (c/n 7977761813264, f/n 0303) piloted by Mikhail S. Deksbakh and Oleg G. Kononenko 'fell through' after clearing the deck of SNS *Minsk* during a short rolling take-off and fell into the sea because the main engine nozzles had failed to assume the correct (vertical) position. The crew ejected from the sinking aircraft; Deksbakh was lucky, parachuting directly onto the carrier's deck without getting his feet wet. Kononenko was less lucky – he landed in the drink and was forced to use his survival equipment. Yet, at least he survived – this once; the next time he would be far less lucky in similar circumstances...

In the summer of 1991 the American pilots Alan Preston and David Price had a 'personal acquaintance' with the Yak-38U at Kubinka AB, courtesy of the Yakovlev OKB. Both were former US Navy pilots, and since 1991 co-owners of the Planes of Fame museum in Santa Monica, California. They came to Moscow at the invitation of the the Yakovlev OKB's General Designer Aleksandr N. Dondukov. Yakovlev OKB chief test pilot Andrey A. Sinitsyn gave both of the American pilots a single check ride in the Yak-38U; Preston and Price became the first foreigners to fly the Soviet 'jump jet'. They noted that the Yak-38 had benign handling and could be flown by ordinary pilots of average skill.

At the MAKS-95 international airshow in Zhukovskiy on 21st-26th August 1995 a Yak-38U coded '07 Yellow' (f/n 0207) flown by LII test pilots Yevgeniy M. Kozlov and Aleksandr V. Krootov took part in the flying display. After that the machine sat on the LII hardstand for a long time.

The trainer's NATO reporting name was *Forger-B*.

Yak-38 Attack Aircraft with VSPU-36 Cannon Pod and Design Changes

As mentioned in Chapter 2, the Air Force SOR for the Yak-36M light attack aircraft require the aircraft to feature two *izdeliye* 225P internal cannons with 80 rpg. Additionally, the external stores were to include UPK-23-250 canon pods with GSh-23 twin-barrel cannons. In May 1970, however, the Air Force command revised the SOR with the purpose of standardising the cannon armament of Soviet warplanes; now the Yak-36M was to carry one

This desktop model represents the radically redesigned Yak-36P interceptor with low-set wings, an R79V-300 main engine, three lift engines and a radar. This project is described in Chapter 2.

Yak-38 '28 Yellow' was used for tests involding VTOL operations on a small metal landing pad at Saki.

GSh-23 cannon in a ventral pod. Such a pod accommodating the cannon and 160 rounds for it was designed designed in house by OKB-115. It was designated VSPU-36 (***vstroy**ennaya **push**echnaya oosta**nov**ka* [*samol**yo**ta Yak-*]***tri**dtsat' shest'* – built-in cannon installation of the Yak-36 aircraft). Actually the 'built-in' bit was rather misleading, as the VSPU-36 was an easily detachable conformal pod mounted aft of the main gear units. This obviated the need to alter the fuselage structure.

In December 1980 OKB-115 submitted the aforementioned Yak-38 '46 Yellow' (c/n 7977864503511, f/n 0104) – the former etalon for the second half of 1978 – for check-up tests. The aircraft had been modified – the horizontal tail now featured reduced anhedral (8° instead of 15°), and two pairs of longitudinal strakes (recirculation dams) were added above and below the centre fuselage in the area of the lift engines. For the purpose of enhancing the aircraft's combat potential, provisions were also made for carrying the VSPU-36 cannon pod.

Special flight tests of this machine were held to ascertain the safety of using the experimental cannon installation (that is, make sure that blast gas ingestion would not cause the engine to flame out) and assess the aircraft's stability, handling and durability with the new weapons option. The test programme envisaged 23 flights. Actually GNIKI VVS test pilots Viktor V. Vasenkov and Nikolay P. Belokopytov made 20 flights in the modernised plane between 29th December 1980 and 10th April 1981. V. A. Doodarev was the machine's engineer in charge.

Yak-38 Attack Aircraft with VSPU-36 Pod and More Design Changes

In March 1982 the Yakovlev OKB submitted another Yak-38 (c/n 797786...174635, f/n 0312) for check-up tests. As compared to Yak-38 '46 Yellow' modified in 1980, the machine introduced even more changes;

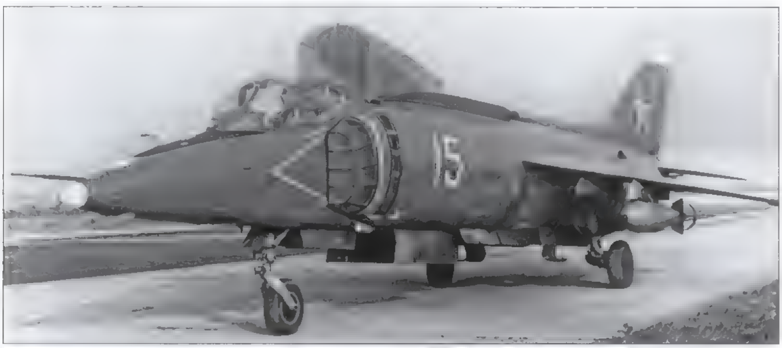
- the forward fuselage design was altered to permit installation of a new PVD-18G-3M pitot;
- the dorsal strakes continued all the way aft to frame 18 to improve the lift engines' operating conditions;
- the aircraft was powered by modified RD36-35FVR (*izdeliye* 28) lift engines uprated to 3050 kgp (6,720 lbst) each and an R27V-300 lift/cruise engine readjusted to increase the take-off thrust to 6100 kgp (13,450 lbst) in vertical thrust mode and 6,800 kgp (14,990 lbst) in maximum horizontal thrust mode when the 10% air bleed for the reaction control system was cancelled);
- a throttle gate was added to prevent the engines from running too hot;
- an oxygen feed system for the lift engines was added to enhance starting reliability;
- the aileron suspension brackets were redesigned;
- a new PTK-38 brake parachute with an area of 17 m² (183 sq ft) was introduced;
- the reduced-anhedral stabilisers (with 8° anhedral) were installed;
- the designers reverted to the detachable wings of early example;
- a centreline hardpoint was added for for carrying the VSPU-36 cannon pod.

Also, the machine sported a non-standard finish – it was painted light grey instead of the usual dark blue with dark green undersides. Interestingly, the upgraded Yak-38 f/n 0312 sported the same tactical code '46 Yellow' as Yak-38 f/n 0104 described above, which had the standard maritime colour scheme.

The tests of Yak-38 f/n 0312 proceeded at Kirovskoye AB and aboard the carrier SNS Novorossiysk in the Black Sea from 31st March to 20th November 1983. 164 flights were made within this period, 79 of which were credited as test tests under the programme. Ten of the flights were made from the carrier. A. I. Yakovenko and N. S. Domonetsky were the project test pilots, with V. A. Doodarev as engineer in charge. The tests revealed a number of shortcomings. In particular, the military were dissatisfied with the machine's longitudinal stability and control then the VSPU-36 pod and some other variants of external stores were carried. Besides, the cannon's case ejector turned out to be defective; as a result, the spent shell cases ejected during gunnery struck the rear fuselage.

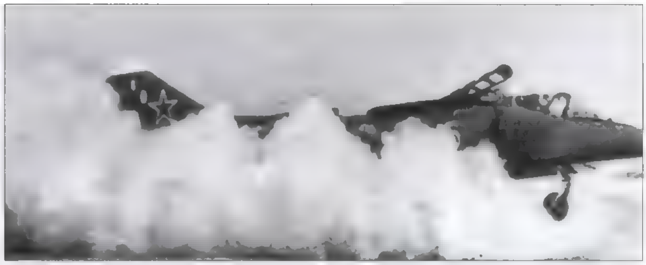
Renewed check-up tests of Yak-38 '46 Yellow' (f/n 0312?) were held between 6th October and 17th November 1983 – again with the cannon pod. This time GNIKI VVS test pilot V. A. Rossoshanskiy flew the machine, making 16 flights, Doodarev was engineer in charge once again. The results appeared satisfactory; nevertheless, the Navy decided against equipping production Yak-38s with the VSPU-36.

However, the issue of fitting the cannon pod came up again in 1988. After appropriate modifications to the aircraft GNIKI VVS conducted one more special test programme between 18th February and 14th March 1988. This time A. Fokin was the project test pilot and A. Shemyakin was the engineer in



Yak-38 '15 Yellow' was used by LII for exploring the short take-off technique. FOD screens were fitted to all air intakes; the FAB-250M62 bombs were merely ballast to prevent a premature take-off.

Here, '15 Yellow' makes a short rolling take-off from a mobile ski jump developed for *ad hoc* tactical airstrips.



Above and below: These photos show the same Yak-38 making shhort rolling take-offs from a dirt strip at Zhukovskiy. This is when the FOD protection devices come into their own!

Left: Close-up of the FOD protection screens fitted to '15 Yellow'. Several models of these screens were used.

charge. the concluding part of the test report said, '...the characteristics of the Yak-38 aircraft with the VSPU-36 and all weapons options with the SAU-36 operating in oscilation damping mode are satisfactory and provide safe performance of flight modes'.

In June-August, 1989 one more special flight test programme was held to validate the modofocations meant to stop the spent cases from striking the rear fuselage. OKB test pilots V. Makagonov and M. Molchanyuk made eight flights; the engineers in charge were A. Shemyakin (GNIKI VVS) and V. Khromov (Yakovlev OKB). As a result, the VSPU-36 cannon pod was finally recommended as a regular weapons fit for the Yak-38 sans suffixe and Yak-38M (see below).

Yak-38I Multi-Role VTOL Aircraft (project)

One more prject under development was the Yak-38I VTOL aircraft (the 'I' is a letter, not a Roman numeral – most probably standing for *istrebitel'*, fighter). Little has been revealed, save that the aircraft was to have been powered by a modified Lyul'ka AL-21 afterburning turbojet.

Yak-38 Multi-Role VTOL Aircraft with Upgraded Landing Gear and Powerplant (project)

Another projected version was to feature an uprated powerplant and a wider-track landing gear whose main units retracted aft into wing fairings.

Yak-39 Multi-Role VTOL Aircraft (Yak-39I, Yak-39Sh, Yak-39UT) (project)

In the summer of 1979 the Yakovlev OKB began preliminary design work on a multipurpose VTOL aircraft designated Yak-39; the project was supervised by Deputy General Designer Kerim B. Bekirbayev. The aircraft was characterised mainly by the installation of a multi-mode radar enabling it to carry medium-range air-to-air missiles and anti-shipping missiles with radar homing at the terminal guidance phase. Outwardly the machine differed from the Yak-38 in having a redesigned fuselage nose incorporating a large radome. The Yak-39 was also supposed to feature increased-area wings and a bigger fuel capacity. The actual design work proceeded under the guidance of project chief A. F. Travin.

Different models of radar were considered, including the Phazotron N019 fire control radar borrowed from the MiG-29 tactical

These pictures show Yak-38s '73 Yellow' and '74 Yellow' (c/ns 797786...286815 and 797786...286840) making short take-offs from SNS *Novorossiysk* during special tests (note the cameramen in the photo on the right). The aircraft have the late-model dorsal and ventral recirculation dams.

fighter and the Shkval (Gale) radar developed for the Sukhoi Su-25T 'tank buster' and the Kamov Ka-50 Black Shark attack helicopter. Unlike the Su-25T, the radar was to be built into the fuselage nose, not carried in a pod. The advanced equipment was also to include the Kaira (Great auk) laser rangefinder.

According to MAP order No. 480 dated 27th October 1981 the OKB was to complete the ADP of the Yak-39 in the second quarter of 1982. Before that, in December 1981, it was required to submit the project materials for review to Vice-Minister of Aircraft Industry Ivan S. Silayev and the Commanders-in-Chief of the Air Force and the Navy. In 1982 S. A. Sirotin became the Yak-39's project engineer.

The aircraft came in three versions at once. The ADP of the basic fighter version designated Yak-39I (for *istre**bi**tel'*) and equipped with a Phazotron S-41 fire control radar (the latter was intended for the Yak-41 VTOL fighter then under development – see Chapter 6), was to be presented to the mock-up review commission in the first quarter of 1983. The Yak-39Sh shipboard strike variant (*shtoormo**vik*** – attack aircraft) was to follow suit in the fourth quarter of the same year. The third version was the Yak-39UT dual-control trainer (*oo**cheb**no-treni**ro**vochnyy* – for conversion and proficiency training).

In February 1983 OKB-115 received orders to submit the Yak-39 for State acceptance trials in the second quarter of 1985; thus, the basic powerplant components (the main and lift engines) were to undergo their State acceptance trials in the first quarter of 1984. To this end the OKB planned to construct four single-seat prototypes in 1984-86 and one Yak-39UT trainer prototype in 1987.

On 6th April 1983 Ivan S. Silayev chaired a meeting at the Ministry of Aircraft Industry. A report was made on the Yak-39 programme's progress. Chief Designer Oleg N. Favorskiy supervising the development of the R28-300 (*izdeliye* 59) turbojet which was selected as the lift/cruise engine for the new aircraft, announced that the engine was ready for production. At this meeting the management of OKB-115 offered to build the Yak-39UT trainer in addition to the combat versions; however, Silayev rejected the idea, stating that the Yak-38U (*izdeliye* VMU) already existed and there was no immediate need for another trainer.

At the meeting Favorskiy suggested that the more refined R30V-300 lift/cruise engine be used to power the Yak-39 instead of the R28-300, which had been developed for the updated Yak-38M shipboard attack aircraft. The R30V-300 turbojet was a cross-breed between the R28-300 and the R79V-300 (*izdeliye* 79, the engine intended for the Yak-41), combining the R28's low-pressure compressor and vectoring nozzles with the high-pressure compressor and the combustion chamber of the R79; the turbine represented a hybrid of both products. According to the manufacturer's estimates, the new lift/cruise engine was just 100 kg (220 lb) heavier than the R28-300. The participants of meeting took Favorskiy's suggestion into account; yet, installing the still 'green' and untried engine, which was bound to have teething troubles, on the projected aircraft at once was considered too high a risk. They also deemed it necessary to modify the lift engines intended for the Yak-39 (*izdeliye* 48) by incorporating vectoring nozzles.

In May 1983 it was decided that the first prototype Yak-39 would be completed in second quarter of 1985, followed by the static test airframe in the fourth quarter of that year and by the second prototype in the fourth quarter of 1986. The designers estimated that the Yak-39 could be used equally effectively as a strike aircraft and as an interceptor. Eventually, however, the project was abandoned, the designers concentrating instead on the more promising Yak-41.

STOL Technique Tests

From the very beginning the Yak-36M was designed with the ability to make short rolling take-offs in mind. The short take-off (STO) technique allowed it to lug a greater payload, as it did not require a thrust/weight ratio in excess of 1, and saved fuel.

Interestingly, shortly after the US Marine Corps had fielded the McDonnell Douglas AV-8A Harrier (the American version of the land-based Harrier GR.1 attack aircraft), the US military came to the conclusion that its combat efficiency was extremely low. In vertical take-off mode with an ordnance load of 1,360 kg (3,000 lb) the AV-8A's radius of action was only 92 km (57 miles). Increasing the range to 500-700 km (310-495 miles) was possible only by using the STO technique, which negated the ability to operated from concealed ad hoc landing pads. Therefore in 1972 the Americans decided that the AV-8A could not meet the requirements of the coming decade. (This led to the development of the much-improved AV-8B and AV-8C.) Great Britain, however, started exploring the STO technique making use of a ski jump and used it successfully on the Royal Navy's aircraft carriers HMS *Ark Royal* and HMS *Invincible* (hence the sobriquet 'ski-jump jet' sometimes applied to the Harrier).

Western aviation experts have been convinced that the mixed powerplant of the Yak-38 did not allow it to perform short rolling take-offs. It seemed that the lift-jets and the main engine would be simply impossible to synchronise; a very complex electronic control system (which did not exist yet at the time) was required. Moreover, proceeding from the experience gained with the Mikoyan '23-01' and Sukhoi T-58VD STOL technology demonstrators in the 1960s, TsAGI's experts gave the verdict that in a short rolling take-off the interference between the slipstream and the exhaust jets of the Yak-38's three engines would eat up 60% (!) of the available thrust, meaning that the machine would not manage to become airborne at all.

However, the Yakovlev OKB did not subscribe to this point of view. Working under the direction of Viktor N. Pavlov, leading engineers V. I. Latyshev and L. V. Staurina, engineer in charge of flight tests Yuriy V. Pronyakin, LII experts Anatoliy I. Kvashnin, Ilya A. Rozenfeld, B. N. Sas and L. I. Vernyy made the necessary calculations and proved by experiment that the Yak-38 was capable of short take-offs. The support of Yu. I. Goosev, the chief designer of the R27V-300 lift/cruise engine, also played an important role.

The STO research programme began with high-speed taxi runs at Zhukovskiy. To prevent foreign object damage (FOD) the air intakes of the main and lift engines were provided with protective devices made of Lavsan mesh stretched over specially shaped

Experiments were made with operating the Yak-38 from commercial freighters. Here the aircraft is seen landing on the 'ro-ro' container ships M/V *Agostinho Neto* (left) and M/V *Nikolay Cherkasov* (which already has one Yak-38 on the deck). The ventilation riser superstructures complicated the operation considerably.

frames. (Lavsan® is a Soviet polymer very similar to nylon; the name is an acronym for *Labora**tor**iya vysokomokeku**lyar**nykh soyedi**neniy** Aka**dem**ii na**ook*** – the [Soviet] Academy of Sciences' High-Molecular Compounds Laboratory.) The aircraft was weighed down as much as possible to prevent an inadvertent take-off. 14 taxi runs were made by LII test pilot Oleg G. Kononenko on 19th October – 5th December 1978. These tests made its possible to determine the speed at which the hot exhaust gases were no longer ingested when the lift/cruise engine nozzles were rotated into take-off position (25° from the vertical). The runs started with a speed of 20 km/h (12.4 mph); after each run the test equipment data on the air temperature at the engine inlets were carefully analysed, and only then did the engineers give the go-ahead to increase the speed at which the nozzles were vectored to take-off position. This painstaking work yielded results: it turned out that at 60 km/h (37 mph) and higher speeds there was no exhaust gas ingestion. Adding another 20 km/h for good measure, the engineers determined the speed at which thrust vectoring in STO mode could begin as 80 km/h (50 mph).

Further experiments were concerned with increasing the ordnance load. As a result, in short take-off mode the Yak-38 could carry up to 2,000 kg (4,410 lb) of weapons – twice the figure permitted in vertical take-off mode!

In 1977 the Yakovlev OKB started experimenting with landing the Yak-38 in short rolling mode (the so-called 'slip technique'). The reason was that the hover and vertical landing modes imposed a lot of stress on the pilot, and the new technique was meant to simplify the approach and landing procedure, enhance flight safety, reduce the time and distance required for landing and boost the powerplant's operating reliability. It was necessary to estimate the possibility and safety of short rolling landing and develop recommendations to be included in the Yak-38's flight manual.

On 29th November 1978 the OKB began 'special flight tests in order to evaluate flight safety during short landings (using the "slip technique")'. Again, the fourth prototype Yak-38 (VM-4) was fitted with Lavsan mesh FOD protection screens on the air intakes to preclude ingestion of concrete particles dislodged from the runway surface.

A GNIKI VVS test team detached to the Yakovlev OKB's flight test facility in Zhukovskiy performed the tests between 12th December 1978 and 9th January 1979. Air Force test pilots Vladilen P. Khomyakov and Viktor V. Vasenkov required 27 flights to complete the programme. N. M. Kozenchuk was the engineer in charge of the tests. The position of the main engine nozzles varied from 0° (vertical) to 15° aft; the landing speed changed from 20 to 100 km/h (12.4-62 mph) in crosswinds gusting up to 5 m/sec (10 kts). The landing run at a touchdown speed of 50-60 km/h (31-37 mph) amounted to 80-100 m (260-330 ft), and the in-flight deceleration stage was reduced by just 5-6% in comparison with a vertical landing. As the landing speed increased, so did the required runway length, and considerably.

Above: Yak-38 '53 Yellow' was one of the four aircraft used in the type's evaluation in Afghanistan.
Below: The same machine after retirement.

The pilots noted that when the machine descended to 1.5-2 m (5-6.5 ft) a 'ground suction' effect took hold, causing a dramatic increase of the sink rate. The aircraft was steady during the descent, and the vibration was less severe than in a vertical landing. The test report read: *'The presence of significant angles of attack on landing with lift/cruise engine nozzles set at 8-15° [from the vertical] creates an inconvenience, complicating the precise calculation of the landing approach. After the mainwheels make contact with the runway and the engines are throttled back to ground idle the aircraft settles down on the main gear units and drops the nose vigorously owing to the sharp drop in the lift engine's thrust. Piloting and landing are complicated in this case, although this technique provides the shortest landing run.'*

The concluding part of the report noted that the short landing technique is recommended in airfield conditions of basing and strictly when landing on special platforms measuring 20 x 170 m (65 ft $7\frac{13}{32}$ in x 557 ft $8\frac{29}{32}$ in) at landing speeds of 50-60 km/h, with the main engine nozzles at up to 8° from the vertical, at crosswind speeds no more than 5 m/sec and angles of attack up to 10°. For the purpose of training aircrews in short landing techniques it was allowed to make practice landings on a concrete runway before going for a real-life carrier landing – on condition that FOD protection screens were fitted to the main engine air intakes. The maximum flight speed with these screens was limited to 50 km/h. The report also pointed out the necessity of carrying out similar tests aboard the carrier, which was to be equiped with an emergency barrier across the deck.

After the VM-4's STO test session in Zhukovskiy, in the summer of 1979 the tests continued in Saki. Test pilot Oleg G. Kononenko made 26 flights there, recommending that the tests be continued aboard the carrier.

STO tests aboard SNS *Minsk* took place on 22nd-27th December 1979 under the programme approved by Vice-Minister of Aircraft

Top and top right: Yak-38 '21 Yellow' (c/n 797786...502409, f/n 0803) was used for experiments with a mobile launch pad based on a trailer. Here the trailer with the aircraft on top is towed by a KrAZ-255B 6x6 heavy-duty lorry.
Above and right: The sidewalls of the platform unfold for action. Note that the aircraft lacks recirculation dams in the area of the lift engine bay.

These pictures probably depict the same aircraft in modified form, with dorsal recirculation dams and an Opushka-VM crash data recorder on the tailcone.

Industry Ivan S. Silayev. A production Yak-38 was involved; Kononenko made 20 flights with a total time of 3 hours 27 minutes and 15 engine runs.

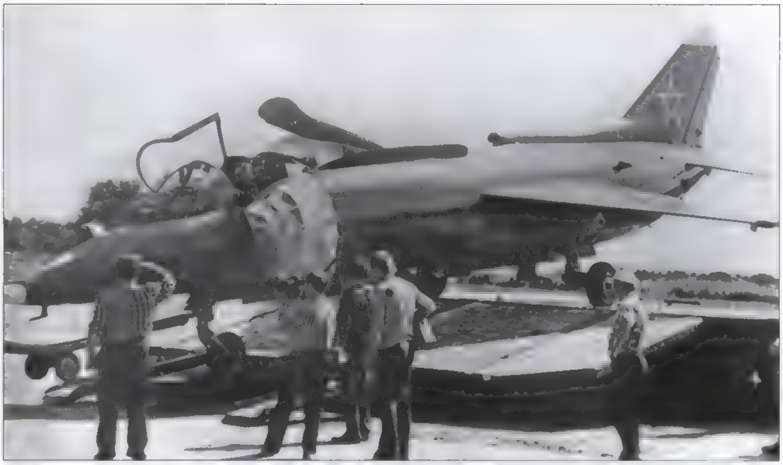
The tests revealed that a short rolling take-off from the ship was possible and the technique was essentially the same as on the shore, except that the take-off appeared more dynamic to the observer. This was because the head wind on a ship's deck is usually stronger than on land, and the take-off run prior to vectoring the nozzles was shorter.

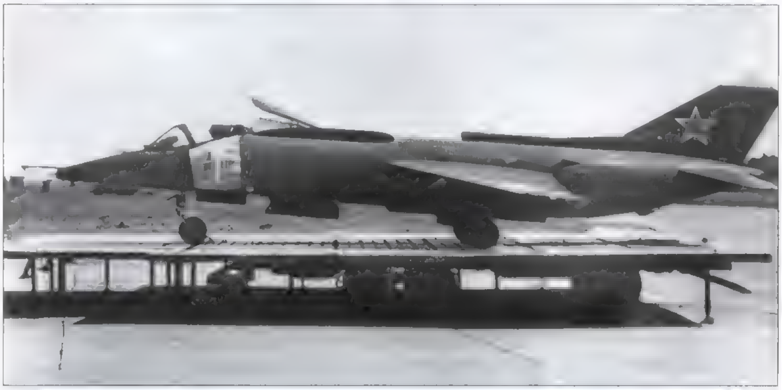
The landing approach was made at low speed (up to 130 km/h; 80.78 mph) with the subsequent landing at a resulting airflow velocity above the ship's deck of approximately 30 m/sec (60 kts). Thus, at the moment of touchdown the aircraft was travelling along the deck at 20-30 km/h (12.4-18.6 mph), and the landing run did not exceed 20-60 m (65-200 ft). However, such landings turned out to be impossible if the ship was rocking with angles in excess of 3°. The STOL technique developed for the Yak-38 made it possible to reduce the fuel consumption and increased the aircraft's combat potential significantly.

The tests aboard the SNS *Minsk* (the results are in the table on the following page) made it possible to polish the STOL technique to perfection. At resulting airflow speeds above the deck of 10-20 m/sec (20-40 kts) and rocking angles up to 4° the aircraft accelerated along the deck to 80-90 km/h (50-56 mph) IAS, then the lift/cruise engine nozzles were rotated to 25° from the vertical and the machine became airborne at 110-120 km/h (68-74 mph) IAS, increasing the angle of attack to 10°. When the speed reached 220 km/h (136 mph) the nozzles were vectored to 45°, and at 320-330 km/h (199-205 mph) the nozzles were incrementally rotated to forward thrust position . The take-off run was 48-75 m (160-260 ft), depending on the velocity of the airstream above the flight deck.

On landing the aircraft touched down, travelling at about 50 km/h (31 mph) with respect to the ship. The velocity of the airstream above the deck was 72 km/h (45 mph) and the indicated airspeed at the moment of touchdown was 120 km/h (75 mph).

Concurrently, Yak-38U '09 Yellow' (c/n 7977761813264, f/n 0303) was undergoing





Top left: Oleg G. Kononenko, the pilot who performed the special tests of the Yak-38 on the mobile launch platform.

Top: Equipped with FOD prevention screens, the aircraft is rolled onto the ramp before a take-off. Interestingly, it has the recirculation dams but lacks a tactical code – and the Opushka FDR, suggesting this is a different example. Yet, it has likewise been referred to as f/n 0803!

Centre, above and right: The uncoded Yak-38 makes take-offs from and landings on the mobile platform, which appears to be of a different model.

Top: '82 Yellow', the first prototype Yak-38M (*izdeliye* 82-1).
Centre and above: '82 Yellow' undergoes trials with FOD protection screens.

The results of STO tests aboard the SNS *Minsk*

Type of take-off	Vertical	Short
Fuel consumption, kg (lb):		
on take-off	360 (790)	280 (620)
on landing	240 (530)	120 (265)
Fuel quantity, kg (lb)	1,350 (2,980)	2,750 (6,060)
Combat radius at +30°C (86°F) and p = 760 mm Hg, km (miles):		
at 200 m (660 ft)	75 (46.5)	260 (161)
at 10,000 m (32,810 ft)	150 (93)	350 (217)
Maximum take-off weight, kg (lb)	10,300 (22,710)	11,300 (24,910)
Weapons load at +15°C (59°F)	500 (1,100)	1,500 (3,310)

short take-off tests; Mikhail S. Deksbakh and Oleg G. Kononenko made 14 flights totalling 3 hours 09 minutes in this machine and and performed 11 engine runs. In parallel, GNIKI VVS test pilots Vladilen P. Khomyakov and Nikolay N. Shlykov flew both single- and two-seat versions in STOL mode, but their flights were part of the State acceptance trials.

As mentioned earlier, on 27th December 1979 Yak-38U f/n 0303 was lost in an accident while making a test flight from SNS *Minsk* in Ussuri Bay in the Far East; pilots Deksbakh and Kononenko had to eject literally out of the water. The aircraft sank but was subsequently salvaged, and the cause of the crash was traced to a faulty electric contact in the lift/cruise engine's nozzle control circuit. As a result, the nozzles had failed to rotate downwards at the right moment, the main engine not providing enough lift.

In February 1980 MAP, the Ministry of Shipbuilding, the Air Force and the Navy agreed to develop jointly a long-term programme directed at boosting the Yak-38's combat potential. In 1981 it was planned to finish the type's STOL mode tests. At the AVMF's shipboard aviation aircrew training centre in Saki a special runway emulating the flight deck of a *Kiev* class carrier was built. Test flights performed by Deksbakh (from OKB-115), Kononenko (from LII) and Khomyakov (from GNIKI VVS) made it possible to finalise the STOL technique for the Yak-38. In comparison with the first variant of the technique tried on the SNS *Minsk*, it proved possible to increase the weapons load by another ton and extend the combat radius to 400 km. In a short rolling take-off the main engine nozzles were set 67° from the vertical from the very beginning. Depending on the speed and elapsed time the nozzles turned automatically at certain angles (manual control was also possible). In a dead calm, the Yak-38 passed about 140 m (460 ft) along the 'deck' of the 'unsinkable carrier' before lifting off at 100-110 km/h (62-68 mph); in a 10-20 m/sec (20-40 kt) headwind the take-off run was shortened to about 90 m (295 ft). When the aircraft accelerated to 400-420 km/h (248-261 mph), the nozzles rotated to the horizontal position and the lift engines shut down. The take-off weight reached 12,800 kg (28,220 lb), including about 2,500 kg (5,510 lb) of ordnance.

In August 1982 Yakovlev OKB test pilot Yuriy I. Mitikov and LII test pilot Valeriy V. Nazaryan successfully made a series of short take-offs with varying payloads and with different take-off runs. Next, having made several take-offs from land and from the carrier, GNIKI VVS test pilots Col. Vladilen P. Khomyakov and Col. Viktor V. Vasenkov stated their appraisal of STO flights with various ordnance loads and developed recommendations for service pilots. Proceeding from the test results, the main engine's automatic nozzle control system and the system controlling the two-position nozzle of the lift engine were recommended for production. The modifcations had proved their worth.

Operation *Romb*

In March 1980 the then Minister of Defence Marshal Dmitriy F. Ustinov gave orders to conduct 'special tests' of the Su-25 and Yak-38 attack aircraft 'in special conditions'. Since the Afghan War was already on, in plain language this meant the aircraft were to be tested in actual combat. An MAP meeting at which the decision was made to send two Su-25s and four Yak-38s to the Afghan theatre of operations took place in early April 1980. The appropriate order No. 0022 was signed by the Air Force Commander-in-Chief on 14th

April. The service evaluation of the new attack aircraft in actual warfare conditions, and also in 'hot-and-high' conditions, was codenamed Operation *Romb* (Rhombus).

Maj. Gen. V. V. Alfyorov (the deputy chief of GNIKI VVS for scientific work) was appointed head of Operation *Romb*. The trials programme included an assessment of the two types' suitability for 'hot-and-high' operations and their combat efficiency in these conditions. GNIKI VVS test pilot Viktor V. Vasenkov was appointed commander of the ad hoc test squadron.

Since the blue naval camouflage was totally inappropriate in Central Asia, the Yaks were temporarily repainted in brown/green tactical camouflage. Of course no recommended painting scheme existed, and the paint crew arranged the differently coloured areas as they saw fit. On 18th April 1980, when all necessary support equipment had been prepared, the evaluation task force redeployed to Shindand in northern Afghanistan. Shindand airbase was located on a mountain plateau 1,140 m (3,740 ft) above sea level and featured a concrete runway 3,200 m (10,500 ft) long. A second runway made of perforated steel plate (PSP) was constructed alongside. Upon arrival the team unloaded the materiel and pitched tents where they would live for the duration. The following day, on 19th April, four Antonov An-22 Antey heavy transport arrived at Shindand, delivering four Yak-38s coded '25 Yellow', '53 Yellow', '54 Yellow' and '55 Yellow' (their construction numbers were 7977861047649, 7977861052651, 7977861052658 and 7977861054666, but no c/n to tactical code tie-ups are known). After unloading the crew started preparing the machines for flights. The four Yak-38s deployed to Afghanistan differed from earlier production machines in having the stabiliser anhedral reduced from 15° to 8° with the purpose of improving longitudinal stability and in having dorsal strakes (recirculation dams) protecting the lift engines from the hot exhaust gases. Their engines had been adjusted to provide 500 kgp (1,100 lbst) of extra thrust, and an oxygen feed system was installed to facilitate starting the lift engines in the rarefied mountain air.

Preliminary maintenance was undertaken on 21st April, and flight operations began two days later. Most of the flights were performed in STOL mode. The Yaks mainly used the concrete runway because the PSP runway was no good – it was ruined by the very first vertical take-off and had to be repaired. Later, four short rolling take-offs were performed from it, but after each take-off the PSP runway had to be inspected and cleaned.

The ambient air temperature ranged from +15°C (59°F) at night to +35°C (95°F) in the afternoon. In these conditions the powerplant's overall thrust loss could reach 1,500 kgp (3,310 lbst). The Yaks left the ground after a run of 200-250 m (660-820 ft). The aircraft accelerated lazily – in these conditions it was clearly short on thrust. The ordnance load, too, was a mere 500 kg (1,100 lb).

The Yak-38s were flown by the detachment commander Viktor V. Vasenkov, MAP test pilot Yuriy I. Mitikov, AVMF pilots Yuriy N. Kozlov, Ye. M. Alifanov, V. G. Panasenko and A. P. Krivulya. The detachment's technical staff was also mixed.

The MAP team of specialists included in the detachment was supervised by chief designer Viktor N. Pavlov. He was assisted by V. G. Kuznetsov (responsible for the special equipment), V. M. Il'yin (armament) and R. N. Novikov (powerplant). The engineers in charge of the tests were S. A. Semyonov from OKB-115 and A. I. Lozhkin from GNIKI VVS. LII was represented by B. N. Sas, the Saratov aircraft factory by A. M. Kuvshinov, while the AVMF team of specialists worked under the supervision of V. V. Kooptsov.

The flying programme was completed on 29th May 1980. By then the four Yak-38s had flown 107 sorties in pairs and singly; they were invariably escorted by Sukhoi Su-17 fighters-bombers which were based at the same airfield. By comparison, the two Su-25s involved in Operation Romb flew 100 sorties.

The evaluation showed that in order to operate effectively in 'hot-and-high' conditions the Yak-38 required design changes and modifications. Some of the recommended modifications were later implemented on the upgraded Yak-38M (see below). In particular, the extreme conditions of 'hot-and-high' operations revealed the need to improve the take-off and acceleration characteristics during a short rolling take-off. After making the necessary calculations Viktor N. Pavlov together with deputy project chief R. N. Novikov and LII expert B. N. Sas made the decision to tilt rear lift engine's nozzle 15° aft (thus placing it in line with the engine's longitudinal axis). As a result, the aircraft began accelerating normally with the design take-off weight. Subsequently all Yak-38s were thus modified.

The report on the results of evaluation stated:

'1. The Yak-38 aircraft designed for shipboard operation possesses has limited combat capabilities when operating from mountain airfields as regards field performance, tactical radius of action and ordnance load due to the insufficient thrust/weight ratio, and also due to the insufficient gunnery and bombing accuracy.

2. Combat application of the Yak-38 when operating from mountain airfields with concrete or PSP runways of limited length (up to 500 m [1,640 ft]) and in ambient temperatures of +17...32°C [62-90°F] is possible only in short take-off/vertical landing (STOVL) mode.

3. The Yak-38's tactical radius of action in STOVL mode with a 500-kg [1,100-lb] ordnance load at ambient temperatures up to +30°C [86°F] is 120 km [74.5 miles].'

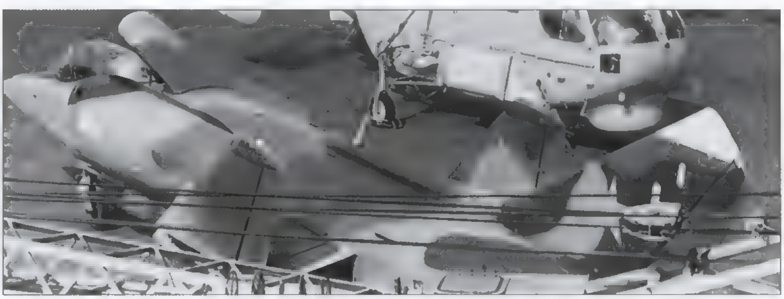
When Operation *Romb* ended, the Yaks returned to Saki where they were repainted back in the standard naval colours.

Tests of the Yak-38 on a Mobile Launch Platform

The steady development of the potential adversary's reconnaissance assets and offensive weapons made the Soviet military revive the idea of dispersing aircraft, using concealed reserve bases, and stealth and surprise action. The USSR also began to pay attention to the issue of using VTOL aircraft on continental battlefields. It was planned to use mobile launch platforms at forward operating locations (FOLs) instead of building ad hoc airstrips. A special research and development programme was begun in order to check the feasibility of operating the Yak-38 from such platforms and check the aircraft's operational characteristics.

The summer of 1980 saw the first tests of the mobile VTOL launch platform. The work was conducted by Yu. V. Stroochkov, Ye. N. Karasyov, G. N. Levykin and test pilot Oleg G. Kononenko; Anatoliy I. Kvashnin supervised the effort.

The thing was based on a production automotive trailer with a capacity of 40 tons (88,180 lb), which was towed by a heavy-duty



The second prototype Yak-38M (*izdeliye* 82-2) aboard the carrier SNS *Tbilisi* in 1990. The aircraft wears an unusual three-tone camouflage scheme.

lorry or tractor. The trailer was equipped with stressed panels that unfolded hydraulically to create an even surface measuring 10 x 15 m (32 ft $9\frac{45}{64}$ in x 49 ft $2\frac{35}{64}$ in) from which the Yak-38 could take off and land vertically. The deployed platform was 1.2 m (3 ft 11 1/4 in) above the ground. The design specifications for the conversion of the trailer were developed by OKB-115's ground support equipment section under the direction of V. T. Mishin.

A production Yak-38 (c/n 797786…502409, f/n 0803) was involved in the tests. There is a controversy concerning the use of this machine in this particular programme. Trustworthy sources indicate that the aircraft used in the tests of the platform was coded '21 Yellow' and lacked the dorsal and ventral strakes (recirculation dams); however, there is also photo proof that the machine had strakes but no tactical code, and the same fuselage number is given in both cases! Perhaps the answer to the riddle is that the aircraft was overhauled and repainted in the middle of the R&D programme, gaining the strakes but losing its identity as '21 Yellow'.

Landing the jet 'on a dime' was extremely difficult, in fact, the pilot could not look directly down and could not see a platform of so small size from the cockpit. The problem was solved by means of an ingenious downward-view optical system for checking the machine's position over the platform. The device underwent tests on a Mi-8 helicopter before being fitted to the Yak-38. Now the pilot could see where he was going to land. To prevent damage to the engines the main and lift engine air intakes were provided with Lavsan mesh FOD protection screens.

From 25th July to 1st August 1980 Kononenko made ten flights which were carried out in two stages. The first of these involved landing within an outline of the VTOL launch platform painted on a conventional runway; it was necessary to make sure that the pilot could descend vertically and land the machine precisely, making use of the optical device. The outline of the platform was applied with due regard to the prevailing wind because the actual platform would also be properly oriented with regard to the wind direction. At the second stage the pilot took off from and landed on the real thing.

Three views of an early-production Yak-38M (f/n 0102). Note the longer dorsal recirculation dams, the larger main engine air intakes, the Opushka-VM FDR and the steerable nose gear unit with lateral doors only (no forward door segment).

Tests showed that taking off from the platform was no problem; however, there was always a danger that the aircraft would start moving when the main engine was revved up in order to start the lift-jets – and roll off the platform. Kononenko noted that landing on the launch platform presented no greater difficulties either, since the optical device allowed him to monitor his position above the platform accurately all the while. The designers came to the conclusion that operating the Yak-38 from a trailer-mounted launch platform was feasible.

In November 1980 Yak-38 f/n 0803 was ready for presentation to the military for operations from the mobile VTOL launch platform. The trials programme included 35 flights and another 26 flights under a separate programme to be held by GNIKI VVS. OKB-115 test pilot Mikhail S. Deksbakh, LII test pilot Vladimir G. Gordiyenko and other pilots were supposed to fly the machine.

In February 1982 no fewer that 96 disruptive camouflage schemes (48 summer variants and 48 winter variants!) were developed specially for the Yak-38 to cater for all possible summer and winter backgrounds found in various geographical regions of the USSR. Apparently they were developed with land-based operations in mind.

Yak-38-80 Shipboard VTOL Aircraft (project)

In 1980 the Yakovlev OKB submitted a technical proposal for an improved version of the Yak-38 tentatively designated Yak-38-80. No details of this project are known.

Yak-38M Attack Aircraft Prototypes (*izdeliye* 82-1 and 82-2)

The Yak-38's combat evaluation in Afghanistan had shown clearly that its thrust/weight ratio was inadequate for flights in 'hot-and-high' conditions, and the customer was also dissatisfied with the aircraft's combat radius. The solution of the problem seemed simple enough – it was necesary to install more powerful engines and introduce the ability to carry drop tanks.

On 27th August 1981 the VPK passed ruling No. 280 concerning the modernisation of the Yak-38 with the purpose of increasing the gross weight, which would increase the payload by 1,000 kg (2,205 lb). The high gross weight version was designated Yak-38M (*moderni***zee***rovannyy* – updated) or *izdeliye* 82. On 20th October 1982 the Air Force Deputy C-in-C (Arms) and the Commander of the AVMF endorsed amendments to the Yak-38's SOR in accordance with which the design work was to proceed.

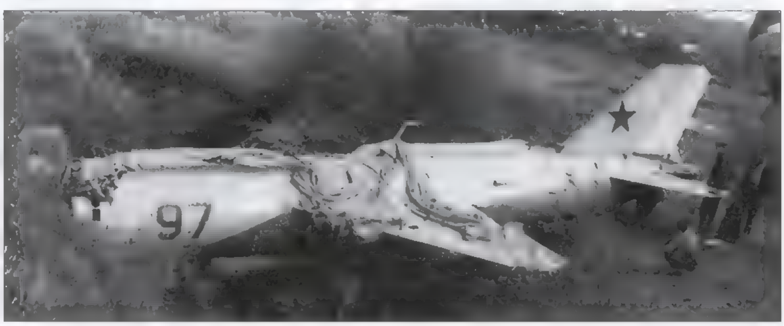
That same year the Saratov aircraft factory set aside two Batch 13 machines (f/ns 0413 and 0513) for conversion as the Yak-38M prototypes known as *izdeliye* 82-1 and *izdeliye* 82-2. The modernisation basically boiled down to installing new and more powerful engines that improved the thrust/weight ratio and fitting 'wet' wing pylons that permitted the carriage of two drop tanks holding 400 kg (880 lb) of fuel each that increased the overall fuel load to 3,550 kg (7,830 lb). Additionally, a steerable nose gear unit was reintroduced.

The first prototype Yak-38M, which was very appropriately coded '82 Yellow', featured only the new powerplant, retaining the castoring nose gear unit and having no provision for drop tanks. The powerplant comprised a Tumanskiy R28V-300 (*izdeliye* 59) main engine rated at 6,700 kgp (14,770 lbst) and two Kolesov (RKBM) RD-38 (*izdeliye* 38) lift engines rated at 3,250 kgp (7,160 lbst) each. The R28V-300 turbojet differed from the R27V-300 (*izdeliye* 49) from which it wasd derived in having a modified low-pressure compressor and a revised nozzle. To ensure steady operation of the lift/cruise enigne the cross-section area of the lateral air intakes was increased. Apart from this, outwardly the Yak-38M differed from the Yak-38 sans suffixe in having bulged lift engine exhaust doors which protruded 45 mm (1$^{49}/_{64}$ in) below the bottom contour of the fuselage. G. A. Fedotov was appointed OKB-115's project engineer for the *izdeliye* 82-1, with V. F. Kopytov as his assistant; Yuriy V. Pronyakin was the engineer in charge of the flight tests.

On 30th November 1982 Yuriy Mitikov made the first two free hovers in '82 Yellow' at Zhukovskiy, taking the machine up to an altitude of 7-8 m (23-26 ft). Next, the first prototype hovered at heights of 5 to 10 m (16-33 ft). Having made sure that the machine was behaving normally, the test team proceeded to CTOL flights; on 18th, 19th and 20th January 1983 Mitikov performed conventional take-offs followed by lift engine starting and deceleration. The first 'full-profile' VTOL flight took place on 10th February.

The manufacturer's flight tests of *izdeliye* 82-1 were broken down in several stages. The first of these (30th November – 14th December 1982) proceeded at the LII airfield in Zhukovskiy. The tests went very intensively. Between 21st December 1982 and 24th March 1983 the machine was based at the GNIKI VVS facility at Kirovskoye AB; on 24th March the prototype redeployed to Saki, where it underwent further testing until 31st May. The manufacturer's tests were completed on 3rd June, the aircraft having logged 17 hours 52 minutes in 44 flights. The results of these tests, which were credited under Stage A of the joint State acceptance programme, were encouraging enough for the Yak-38M to be recommended for production.

'34 Yellow', a production Yak-38M. Interestingly, a considerable number of Yak-38Ms wore this two-tone grey colour scheme.



Yak-38M '97 Yellow' flown by pilot Voronin is depicted after an off-field forced landing.

Above and below: An uncoded Yak-38M operated by LII in standard blue/green colours (probably f/n 0605, one of the last examples built).

'82 Yellow' had an unlucky fate. On 12th April 1985 the first prototype collided with the ground while making a test flight with the maximum take-off weight (11217 kg/24,729 lb) and was destroyed. Test pilot Vladimir P. Makagonov ejected safely.

The second prototype Yak-38M, '83 Yellow', differed from the first one in having a modified fuel system – the wing pylons were plumbed for carrying drop tanks. The system provided priority usage of the fuel from the drop tanks and their normal (when empty) or emergency jettisoning. It also maintained the aircraft's CG as the fuel was burned off. The izdeliye 82-2 also had the intended steerable nose gear unit. When the aircraft taxied under its own power, making tight turns, the nosewheel was power-steerable through ±45°; for ground/deck handling the steering mechanism was disengaged, allowing the aircraft to be towed with the nosewheel turning through ±90°.

Apart from this, the two Yak-38M prototypes featured the following changes: the short rolling take-off mode was automated; a new *Opushka-VM* (Wood clearing) FDR was installed. The aircraft featured an experimental SOS-3-6 audiovisual warning system (*sistema ogranichitel'nykh signahlov* – 'limiting signal system') alerting the pilot if the aircraft's G load, angle of attack and sideslip angle approached critical values. The stabiliser incidence was changed. The instrument panel, rudder pedals and stick were altered, and the canopy now featured a rear view mirror.

On 23rd August 1983 test pilot Andrey A. Sinitsyn began taxi tests of the second prototype at Zhukovskiy, checking out the nose gear steering mechanism. After that, '83 Yellow' was airlifted by an An-22 transport to Saki, where Sinitsyn commenced the flight tests on 7th September. Next, he ferried the second prototype to the GNIKI VVS branch at Kirovskoye AB where the tests continued. Later, the same An-22 took the Yak-38M to Severomorsk-3 AB, a North Fleet airbase near Murmansk. On 8th October 1983, Sinitsyn executed the first free hover in '83 Yellow' and turned the machine over to GNIKI VVS test pilot Col. Viktor Vasenkov.

Stage A of the Yak-38M's joint State acceptance trials began in Severomorsk in October 1983. The trials went very intensively, since the operational problems experienced by production Yak-38s *sans suffixe* in hot and humid climates (the aircraft had trouble becoming airborne!) required the upgraded machine to enter service as soon as possible. On 12th October Vasenkov launched conventionally from Severomorsk-3, making a vertical landing on SNS *Novorossiysk* which was anchored at the nearby Navy base. There he tried out the steerable nose gear as he taxied on the carrier's deck without switching off the lift engines, then took off vertically, hovered over the Nos. 5 and 6 launch pads and

Two views of the uncoded Yak-38M c/n 7977824798494 (f/n 0605) sitting at the Yakovlev OKB's flight test facility with wings folded.

Above: Later the same aircraft received the two-tone grey colour scheme and was coded '88 Yellow', participating in several air displays in this guise.

departed back to Severomorsk, landing conventionally.

The State acceptance trials continued in late May 1984, involving a commercial vessel – the 'ro-ro' class container ship M/V *Nikolay Cherkasov*. GNIKI VVS test pilots Viktor V. Vasenkov and A. I. Yakovenko flew the machine at this stage. All in all, the trials programme included 18 flights.

Stage B of the trials ended in June 1985. Again, the Yak-38M was flown by Vasenkov, while S. A. Semyonov was engineer in charge from OKB-115.

Yak-38M f/n 0605 was part of the aircraft display staged at Moscow-Khodynka in August 1989.

Carrier compatibility tests of the second prototype Yak-38M (*izdeliye* 82-2) took place on 6th-15th July 1987 during the State acceptance trials of the carrier SNS *Baku*. OKB test pilot Yuriy I. Mitikov performed 14 flights at this stage; O.A.Girich was the engineer in charge of the tests, and Yu. B. Viskovsky supervised the test team.

During manufacturer's seagoing tests of the Type 1143.5 CTOL aircraft carrier SNS *Tbilisi* – subsequently renamed SNS (and then RNS, Russian Navy ship) *Fleet Admiral Kuznetsov* – on 8th-25th August 1990 in the Black Sea the second prototype Yak-38M was used to check the possibility of VTOL operations from this ship. It was also used to verify the SOS-3-6 audiovisual warning system. Interestingly, at this stage Yak-38M '83 Yellow' wore a three-tone tactical camouflage instead of the normal dark blue/green finish.

To enable operation of VTOL jets, part of the *Tbilisi*'s flight deck (near the Nos. 3 and 4 launch positions) was covered with AK-9FM heat-resistant tiles; the remainder of the deck was covered with a heat-resistant non-slip coating named *Onega* (after a Russian lake). Despite the simlar project number, the Type 1143.5 carrier was very different from the *Kiev* class (Type 1143) carriers. It was larger overall and had a full-length flight deck terminating in a ski jump at the bows for launching CTOL shipboard aircraft, such as the MiG-29K, Su-27K and Su-25UTG. Hence there were no devices streamlining the airflow over the foredeck (except the forward sponson). The pad for VTOL operations was limited to 20 x 50 m (65 ft 7$\frac{13}{32}$ in x 164 ft 0 in) and was located at the front of the angled deck, 30 m (98 ft 5 in) from the ship's diametral plane.

Aboard the *Tbilisi* the Yak-38M was flown mainly by OKB test pilot V. P. Makagonov, who made six flights. OKB test pilots V. A. Yakimov and M. B. Molchanyuk made two flights each; GNIKI VVS pilots Prigodin (four flights) and Syomkin (one flight) were also involved. In all, the tests aboard the CTOL carrier included 15 flights. V. V. Volkov was engineer in charge of the tests, B. B. Vorob'yov and A. K. Yeliseyev were the aircraft's mechanics, while V. A. Shalygin supervised the entire 'expedition'. Flights were carried out from the portside launch pad No. 4 at ambient temperatures of +22 to +26.8°C (71.6-80.2°F) and airflow speeds ranging from 3 to 15 m/s (6-30 kts); the airflow was directed at 0º to 30º to the ship's longitudinal axis.

The tests resulted in the following conclusion: *'...Accommodation, storage, and all kinds of pre-flight procedures during occasional operation of the Yak-38M aircraft from the heavy aircraft-carrying cruiser Tbilisi are possible, providing the appropriate support equipment is carried'*. You're welcome but bring your own towel and slippers, so to say.

As mentioned above, one of the requirements leading to the Yak-38M's development was longer range. Yet, the new engines were not only more powerful but thirstier as well, and the radius of action without drop even was actually reduced.

Yak-38M Production Attack Aircraft (*izdeliye* VMM; *izdeliye* 82)

The Yak-38M shipboard attack aircraft superseded the basic Yak-38 *sans suffixe* on the Saratov production line in 1984. Production continued until 1988, totalling 50 machines. Again, the same construction number system was used but the second group of digits was 782 (indicating *izdeliye* 82), and the fuselage number sequence started all over again, with ten aircraft per batch.

The upgraded aircraft gradually replaced the forerunner in the shipboard attack air regiments as the old Yak-38s *sans suffixe* ran out of service life. The Yak-38M was officially included into the enventory, but its introduction did not give the desired effect. Flight performance improved only slightly owing to the high specific fuel consumption of the new engines. As noted above, the radius of action on internal fuel was reduced; nevertheless, the Yak-38Ms did see active duty.

From 27th September to 20th October 1986 Yakovlev OKB test pilot Andrey A. Sinitsyn made five test flights in the second production Yak-38M ('48 Yellow', f/n 0102) near Belo'omut, operating from Saratov-Yoozhnyy, to check the separation of the drop

Yak-38 '60 Yellow' (c/n 7977864060699, f/n 1010) was on display at the (now sadly defunct) museum at Moscow-Khodynka.

tanks; in one of these flights the machine's stability with drop tanks was also checked.

Meanwhile, the fourth Type 1143 aircraft carrier, SNS *Baku*, had been laid down at Nikolayev at the end of 1978; in 1991 she was rechristened SNS *Fleet Admiral Gorshkov* to honour the former Soviet Navy C-in-C. She differed a little from the preceding ships in this series: the architecture of the island was changed and the flight deck was extended. Along with subsonic Yak-38 attack aircraft, the carrier wing of the Baku was to include the new supersonic Yak-41 V/STOL fighters. To this end a special jet blast deflector rising behind the aircraft was provided for STO operations.

Manufacturer's seagoing tests and State acceptance trials of SNS *Baku* proceeded in the Black Sea in March-July 1987. The flying part of the test programme featured OKB test pilot Yuriy I. Mitikov flying a production Yak-38 *sans suffixe* coded '61 Yellow' (c/n 7977862397..., f/n 0615). On 13th March that year the same machine launched from Saki to make the first deck landing on the *Baku*. Despite the nasty weather and low overcast characteristic for this time of year, the carrier's crew waited impatiently for the jet to arrive. However, as he approached the ship, Mitikov received incorrect range data from the ship's air defence search radar (as luck would have it, the air traffic control radar used for guiding incoming aircraft was unserviceable). As a result, the lift engines were started too late, and the approach had to be aborted; the Yak thundered over the carrier's d and disappeared in the clouds. Miti recalled that he passed the ship's stern a speed of some 250 km/h (155 mph).

Everyone disappointed, believing that the long-aw d landing was off (there you are – it was 13th day of the month, after all, with all the bad luck it brings) and Mitikov had diverted to one of alternate airfields - Kacha or Saki. After a while, however, the characteristic thunder of jet engines was heard again, and the Yak-38 reappeared from the overcast – moving *back to front*! To the enthusiastic shouts of seamen and pilots Mitikov carefully manoeuvred the machine, setting it down between the Nos. 4 and 5 launch pads. This was possibly the only correct decision in that situation; yet, to pull such a trick the pilot had to know all the unique capabilies of the upgraded aircraft and know how to use them. The skilled test pilot did it brilliantly.

On 15th and 19th March 1987 Mitikov performed five hovers, and on 21st March he flew two 'full-profile' VTOL sorties from the *Baku*'s deck. After that he made five more flights under the ship's trials programme, departing for Kirovskoye AB on 30th March.

A late-production Yak-38M coded '88 Yellow' (c/n 7977824708494, f/n 0605) was used for testing a revised cockpit layout. This aircraft wore an unusual light grey finish with darker grey undersides.

Production Yak-38Ms sometimes participated in various aviation displays and international airshows. Thus, on 19th August 1989 Yakovlev OKB chief test pilot Andrey A. Sinitsyn made a demo flight in Yak-38M '88 Yellow' (c/n 7977821504292, f/n 0702) at the Aviation Day air fest in Zhukovskiy. On 6th-13th September 1992 the same aircraft was demonstrated to the foreign public at the Farnborough International '92 airshow. OKB test pilot V. Yakimov showed what the Soviet 'jump jet' could do. Taking off conventionally, he made a circuit of the field, decelerated to zero speed and hovered at about 150 m (490 ft), then transitioned to forward flight and landed conventionally.

Yak-38MP Multi-Role Shipboard VTOL Aircraft (project)

In addition to the VSPU-36 cannon pod, other ways of increasing the combat potential of the Yak-38 and Yak-38M were studied. For example, the Yak-38M served as the basis for the project of a multi-role aircraft designated Yak-38MP. The machine was to feature a new weapons system, included an S-41 fire control radar developed by NPO Phazotron for the future Yak-41; hence the P suffix probably stood for *perekhvatchik* (interceptor). Another change was the installation of wing leading-edge root extensions (as on the AV-8B).

Yak-38MTs Multi-Role Shipboard VTOL Aircraft (project)

In 1983-84, working under the direction Chief Designer Kerim B. Bekirbayev, the OKB's PD project section headed by Leon M. Shekhter brought out a project of a shipboard aircraft designated Yak-38MTs (*mnogotselevoy* – multi-role). A. F. Travin headed the actual design work. The machine was derived from the production Yak-38M and intended for the following missions:

- attacking average- and large-displacement surface ships with Kh-31 anti-shipping missiles while staying outside the 'kill zone' of the enemy air defence;
- attacking aerial targets with K-27 and K-77 medium-range air-to-air missiles;
- performing all types of missions typical of the Yak-38M;
- joint operations with land forces (including operation from shore FOLs).

The projected Yak-38MTs had the following design differences from the Yak-38:

- the avionics suite included a Ts-060 attitude and heading reference system (AHRS) and a new WCS based on the S-41 fire control radar, which required the forward fuselage to be redesigned and the instrument panel and control consoles to be reconfigured;
- the rear fuselage was stretched, being borrowed from the Yak-38U in order to preserve the CG position and and accommodate the new equipment;
- the fuel system was modified – the capacity of the No. 1 fuel tank was increased and additional fuel tanks were accommodated in the wing roots;
- to improveme the acceleration characteristics the No. 2 RD-38 lift engine was equipped with a vectoring nozzle that could move ±15° from the neutral position.

At that time, however, the development work on the Yak-41 multi-role supersonic VTOL jet was going full steam ahead. The Yak-41 featured not only a very similar weapons system, but also more powerful engines; hence the Yak-38MTs project was deemed outdated and was soon shelved.

Chapter 4

The Yak-38 in Detail

The following description applies to the basic single-seat Yak-38 (Yak-36M). Details of other versions are given as appropriate.

Type: (Yak-38/Yak-38M) single-seat shipboard V/STOL light attack aircraft; (Yak-38U) two-seat conversion trainer.

The airframe is of all-metal construction, with flush riveting throughout. It is predominantly made of aluminium alloys; the main structural material is the grade 01420 Al-Li alloy having high corrosion resistance and a low specific weight (2.47 g/cm³). High-strength steel, high-strength aluminium alloys and heat-resistant titanium alloys are also used for certain components.

Fuselage: Semi-monocoque stressed-skin structure with longerons, stringers and frames. The fuselage cross-section changes from circular (at the forward extremity) to elliptical with the longer axis vertical (in the cockpit area) to circular. The fuselage nose is drooped ahead of frame 15 and upswept aft of frame 29. The fuselage is 15.58 m (51 ft $1\frac{25}{64}$ in) long.

Structurally the fuselage consists of two sections: forward (up to frame 29, which is the fuselage break point) and rear. The latter is detachable for maintenance and removal of the lift/cruise engine; the two fuselage sections are held together by nine fittings and bolts. The fuselage structure is largely made of 01420 aluminium alloy.

The *forward fuselage* (frames 1-29) features regular annular frames and bulkheads; most of the latter are mainframes absorbing structural loads. Frame 29 is a flange-type frame consisting of two matching rings. Bulkheads Nos. 3, 7, 10, 14, 17 and 23 divide the forward fuselage into bays. The forward fuselage skin comprises 35 panels, including 14 riveted panels, six integral stamped panels made of 01420T alloy and 15 cut panels made of 01420 Al-Li alloy, D19I and D19ATV duralumin. The forward fuselage incorporates close to 50 hatches and apertures closed by hinged or detachable panels.

A small glassfibre nosecone forms the forward extremity of the fuselage. It is followed by the forward avionics bay (frames 1-3) with lateral access covers; the forward reaction control puffer is located below this bay.

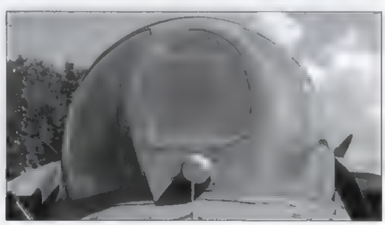
The ventilation-type pressurised cockpit (frames 3-7) is enclosed by a canopy with a light alloy frame comprising a fixed windshield and a section opening manually to starboard. The windshield features an optically flat triplex birdproof windscreen and two curved triangular sidelights made of Plexiglas; the hinged portion has a one-piece blown Plexiglas transparency. The cockpit is equipped with a set of flight controls (stick and rudder pedals), engine controls, an instrument panel and side control consoles. It accommodates the oxygen equipment and some components of the pressurisation and air conditioning system (which see). The cockpit's rear pressure bulkhead has two guide rails for the ejection seat (see Crew escape system). The control runs and wiring exit the cockpit through pressure seals.

The nosewheel well is located below the cockpit between frames 4-10. It features a dome at the rear accommodating the wheel; the nose gear fulcrum is located at frame 5 and the retraction actuator is attached to frame 7. The No. 2 avionics/equipment bay is located between frames 7-10.

A bay delimited by frames 10-14 accommodates the lift engines; it is closed at the top by an aft-hinged intake door with spring-loaded suction relief doors and at the bottom by lateral doors. Frames 10N and 14 are bulkheads acting as firewalls; the rear bulkhead doubles as the front wall of the forward integral fuel tank and is therefore coated with heat insulation. The forward integral fuel tank is located between frames 14-23.

Two fixed-geometry lateral air intakes for the lift/cruise engine flank the fuselage between frames 7-10, blending into the fuselage further downstream. They have semi-elliptical cross-section; the rounded air intake lips are made of D16UMO duralumin. The intakes have trapezoidal boundary layer splitter plates; from c/n 797786...502307 (f/n 0503) onwards a section of the inner wall downstream of the intake is perforated for boundary layer suction. A row of spring-loaded suction relief doors is provided on the outer side of each air intake. The air intakes lead into inlet ducts made of D16AMO duralumin which flank the lift engine bay and the forward fuel tank, gradually merging at frame 23 ahead of the engine compressor face.

To prevent exhaust gas ingestion, pairs of recirculation dams are fitted dorsally between frames 10-18 from c/n 797786...502307 onwards and ventrally between frames 14-17 and 17-29 from c/n 7977863822366 (f/n 0107 onwards. Some of the earlier examples were retrofitted with the recirculation dams.



Top: The dielectric nosecone and pitot probe.
Above, right and top right: The cockpit canopy of the single-seat Yak-38.

Yak-38M shipboard V/STOL attack aircraft - Cutaway drawing key

1. PVD-18G main pitot
2. Dielectric nosecone
3. Active ECM emitter aerial
4. RSBN-36 SHORAN receiver aerial
5. SHORAN and active jammer modules
6. PVD-7 back-up pitot head
7, 8. Communications and navigation/attack suite modules
9. ECM system receiver aerial
10. ASP-PFD-21 computing gunsight
11. Hinged canopy section
12. Zvezda K-36VM zero-zero ejection seat
13. Main engine air intake auxiliary inlet doors
14. Lift engine intake scoop with suction relief doors
15. Kolesov (RKBM) RD-38 lift engine
16. Landing/taxi light
17. Lift engine exhaust doors
18. Single-point pressure refuelling connector access door
19. Tumanskiy R28-300 main (lift/cruise) engine
20. ARK-15M ADF loop aerial
21. Main engine bay cooling air scoop
22. ARK-15M ADF omnidirectional strake aerial
23. External stores pylons
24. Bleed air duct to reaction control nozzle
25. Wingtip reaction control nozzle
26. Lift/cruise engine vectoring nozzle

27. No. 2 fuel tank
28. Tester-UZL flight data recorder
29. Opushka-VM flight data recorder in recoverable buoyant housing
30. RSBN-36 SHORAN slot aerial
31. R860-1 VHF radio aerial

These photos provide a comparison of the main engine air intakes of the Yak-38 *sans suffixe* (left) and the Yak-38M. The latter's auxiliary blow-in doors are closed by ground covers.

The mainwheel wells are located on the centre fuselage sides below the forward fuel tank. Frames 20, 23 and 26 served as attachment points for the wings. On early Yak-38s with non-detachable wings the wing spars were bolted and riveted to the said frames by; on late-production aircraft with detachable wings frames 20, 23 and 26 incorporated fittings to which the wing spars were mated. Additionally, frame 23 carries the main gear fulcrums and the forward attachment points for the lift/cruise engine (the latter are integrated with the middle spar attachments).

The lift/cruise engine bay occupies the remainder of the forward fuselage section (frames 23-29). A shallow fuselage spine begins at frame 23; it incorporates an engine bay cooling air scoop between frames 23-24 and continues aft to blend with the vertical tail. To protect the fuselage structure, equipment and wiring looms from overheating the lift/cruise engine is enclosed by a heat shield extending from frame 23 all the way to frame 31 in the rear fuselage. From Yak-38 c/n 7977862816340 (f/n 0806) onwards the skin of the lift/cruise engine bay below the wing trailing edge between frames 23-28 is coated with the VPFK heat insulating compound.

The *rear fuselage* (frames 29-41) houses the rear end of the lift/cruise engine with its bifurcated jetpipe and rotating nozzles, the rear integral fuel tank (located between frames 31-33), the rear electrics bay and control linkages and actuators. The rear fuselage structure consists of 13 frames, nine longerons and a number of stringers supporting the skin; the latter is mostly made of 01420T alloy and is 1-2 mm (0.039-0.078 in) thick. The underside features special recesses with heat-resistant titanium alloy skin for the rotating nozzles. The rear reaction control puffer nozzle is located at frame 39. A brake parachute container forms the rear extremity of the fuselage.

Wings: Cantilever mid-wing monoplane with wings of trapezoidal planform. Leading-edge sweep 45°, anhedral 10°, incidence 0°, aspect ratio 2.58. The wings utilise the TsAGI P-35S-6 airfoil at the root and the TsAGI S-12S-6 airfoil at the tip. Gross wing area 18.69 m^2 (201.18 sq ft).

The wings are of all-metal, three-spar stressed-skin construction; the spars are attached to fuselage frames 20, 23 and 26. To facilitate on-deck parking and below-deck stowage they are built in four sections and incorporate a power folding feature, the outer wings folding upward hydraulically through 102°; the folding hinges are located 2.2 m (7 ft $2\frac{39}{64}$ in) from the centreline. On early/mid-production examples the wings were permanently joined to the fuselage; Yak-38 c/n 797786…933601 (f/n 0608) and late-production examples from c/n 797786…054678 (f/n 0809?) onwards have detachable wings mated to the fuselage frames by fittings at the root rib.

Each *inner wing* has three spars, a front false spar, seven ribs and 16 stringers. The upper skin panels are made of 01420TL3 aluminium alloy, the lower skins are made of D19ATV2,5 duralumin. The detachable leading edge is made of 01420TL1,2 aluminium alloy – or, from c/n 797786…947630 (f/n 0109) onwards, 01420T alloy – and attached to the false spar by bolts. The inner wings feature four hardpoints for weapons carriage; the inner pylons are located between ribs 3/4 and the outer ones between ribs 6/7.

Each *outer wing* has two spars (the rear spar is an I-beam made of VNS-5Sh high-strength stainless steel), six ribs, a set of stringers, a detachable leading edge made of D16AML2 duralumin and a tip fairing made of D16AM 1 mm thick. The wingtips incorporate reaction control puffer nozzles. The upper and lower wing skins on both inner and outer sections feature numerous maintenance access panels. The wing/fuselage joint is covered by a fillet.

The inner wings have one-piece constant-chord slotted flaps with an area of 1.08 m^2 (11.63 sq ft) each. Maximum flap deflection is 35°. The outer wing trailing edge is occupied by tapered one-piece ailerons having an area

The port wing of a Yak-38M, showing the wing folding hinge, the twin weapons pylons and the wingtip bulges housing reaction control puffers.

The folded wings of a Yak-38 *sans suffixe*, showing the ailerons; the starboard aileron has a trim tab. Note the ECM antennas at the wingtips.

of 0.98 m^2 (10.55 sq ft) each. The ailerons are statically and aerodynamically balanced; the starboard aileron incorporates a trim tab with an area of 0.0453 m^2 (0.49 sq ft). The deflection angles are ±24° for the ailerons and ±17° for the trim tab.

Tail unit: Conventional cantilever swept tail surfaces of trapezoidal planform utilising symmetrical airfoils with a thickness/chord ratio of 6%. The *horizontal tail* comprises two tailplane halves attached to fuselage frames 37 and 38, connecting beams in between and two elevators. Leading-edge sweep 43°, anhedral 15° up to and including Yak-38 c/n 797786...947646 (f/n 0309?) and 8° from c/n 797786...947649 (f/n 0409?) onwards, incidence 0°. Horizontal tail span 3.175 m (10 ft 5 in); gross horizontal tail area 4.447 m^2 (47.87 sq ft).

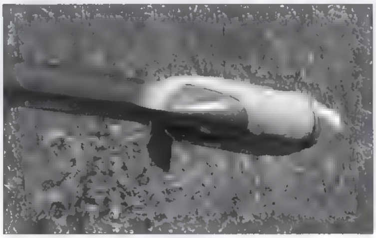
Each tailplane is a two-spar structure with ribs, stringers and skin. The one-piece elevators are hinged to the tailplanes on three brackets each and have an area of 1.142 m^2 (12.29 sq ft) each; the starboard elevator has a trim tab. The tailplane/fuselage joints are faired.

The *vertical tail* consists of a fin and a one-piece rudder. Leading-edge sweep 53°, gross area 4.23 m^2 (45.53 sq ft). The vertical tail has a raked top (the fin has a horizontal rib at the top to which a triangular glassfibre tip fairing enclosing antennas is attached, while the top of the rudder is raked). The leading edge extends into a shallow root fillet blending into the fuselage spine. The fin is bolted to the fuselage at frames 34 and 37. It has a similar two-spar structure with three rudder mounting brackets. The rudder has an area of 0.975 m^2 (10.49 sq ft) and incorporates a trim tab with an area of 0.0453 m^2 (0.49 sq ft). The deflection angles are ±30° for the ailerons and ±17°30' for the trim tab. The fin/fuselage joint is faired.

Landing gear: Hydraulically retractable tricycle type, with single wheel on each unit. All units have semi-levered suspension and oleo-pneumatic shock absorbers. The aircraft has a 2°30' nose-up ground angle.

On the Yak-38 *sans suffixe* aft-retracting castoring nose unit has a K-298 non-braked wheel with a 600 x 150 mm (23.62 x 5.9 in) tyre. Steering is by differential braking. The Yak-38M has a steerable nose unit.

The main units are attached to centre fuselage frame 23 and have KT-61/3 brake-equipped wheels (*koleso tormoznoye*) with 660 x 200 mm (26 x 8 in) low-pressure tyres. The main units retract forward; the main gear fulcrums are skewed so that the wheels turn through 90° during retraction to lie horizontally beneath the air intake ducts. The prototypes and the first ten production Yak-38s had simple main gear struts and a wheel track of 2.2 m (7 ft 2$\frac{39}{64}$ in). On later examples the main units were redesigned to increase the wheel track to 2.75 m (9 ft 0$\frac{17}{64}$ in); the 'dog-leg' main units folded during retraction by means of mechanical linkages, minimising the required space. The wheelbase is 6.06 m (19 ft 10$\frac{37}{64}$ in).



Above: Close-up of the port wingtip fairing incorporating the reaction control nozzle and ECM antennas.

Left: The port BD3-60-23F1 weapons pylons.

On the Yak-38 *sans suffixe* the nosewheel well is closed by a forward door segment mechanically linked to the oleo strut and a pair of clamshell doors at the rear which remain open when the gear is down. The Yak-38M has two pairs of lateral doors. Each mainwheel well is closed by horizontally split forward doors and a rear door segment linked to the retraction ram. The larger doors open only when the gear is in transit.

For rolling landings the Yak-38 features a PTK-36M brake parachute with an area of 13 m^2 (139.9 sq ft) housed in the rear fuselage. The mainwheel tyres can withstand 8-10 rolling take-offs and landings.

Powerplant: The Yak-38 has a combined powerplant. Early examples were powered by a single Tumanskiy R27V-300 lift/cruise engine rated at 5,900 kgp (13,010 lbst) in lift mode and two Kolesov (RKBM) RD36-35FV lift engines rated at 2,900 kgp (6,390 lbst) apiece.

The R27V-300 (*izdeliye* 49) is a two-spool axial-flow non-afterburning turbojet having a simple inlet with a parabolic spinner and no inlet guide vanes, a five-stage low-pressure (LP) compressor, a six-stage high-pressure (HP) compressor, an annular combustion chamber, a single-stage HP turbine with air-cooled blades, a single-stage LP turbine and a bifurcated subsonic nozzle with downward-angled 'trouser legs' terminating in curvilinear vectoring nozzles which allow the thrust to be directed downward for hover or aft for cruise flight. The nozzles are actuated by individual hydraulic motors and synchronised by a torsion shaft.

The compressor features bleed valves. The turbine stator vanes are air-cooled. The ventrally located accessory gearbox carries the DC starter/generator, AC generator, hydraulic pump, fuel pump/regulator, oil pump and other accessories.

The engine has an automatic fuel feed system, a closed-loop lubrication system with an oil tank on the port side of the engine casing. Starting is electric, using ground or shipboard power, and automatically controlled.

Engine pressure ratio 10.5, mass flow at take-off power 100 kg/sec (220 lb/sec), turbine temperature 1,440°K, cruise specific fuel consumption (SFC) 0.883 kg/kgp·hr. Dry weight 1,350 kg (2,980lb), length overall 3,700 mm (12 ft 1 43/64 in), engine diameter 1,012 mm (3 ft 3 27/32 in).

The RD36-35FV (*izdeliye* 24) is an axial-flow non-afterburning turbojet having an air intake assembly with a fixed spinner and multiple radial struts, a six-stage compressor with a supersonic first stage separated from the other five by a spacer, a short annular combustion chamber, a single-stage turbine with air-cooled blades and stator vanes, and a fixed-area convergent subsonic nozzle. The latter can be set at different angles with respect to the engine axis. The spool rotates in two bearings; the forward support incorporates a vibration damper.

The fuel pump is housed in the intake spinner and driven directly off the compressor shaft. The automatic circulation-type lubrication system has no oil pump. Starting is by bleed air from the lift/cruise engine on the ground or by windmilling in flight.

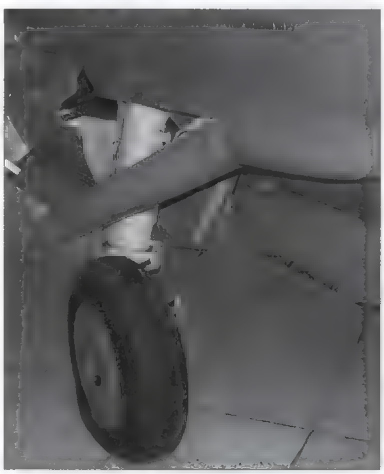
Mass flow at take-off power 45.3 kg/sec (99.8 lb/sec). SFC at take-off power 1.38 kg/kgp·hr (lb/lbst·hr). Dry weight 201.5 kg (444 lb). The engine's service life is 670 cycles. The RD36-35FV was manufactured by the Rybinsk Engine Factory (RMZ).

From c/n 797786...171590 onwards the Yak-38 *sans suffixe* had two RD36-35FVR (*izdeliye* 28) lift engines uprated to 3,050 kgp (6,720 lbst) each and an R27V-300 lift/cruise engine adjusted to provide a maximum thrust of 6,100 kgp (13,450 lbst) in lift mode and 6,800 kgp (14,990 lbst) in cruise mode. (Some sources state a maximum take-off thrust of 6,900 kgp (15,210 lbst).)

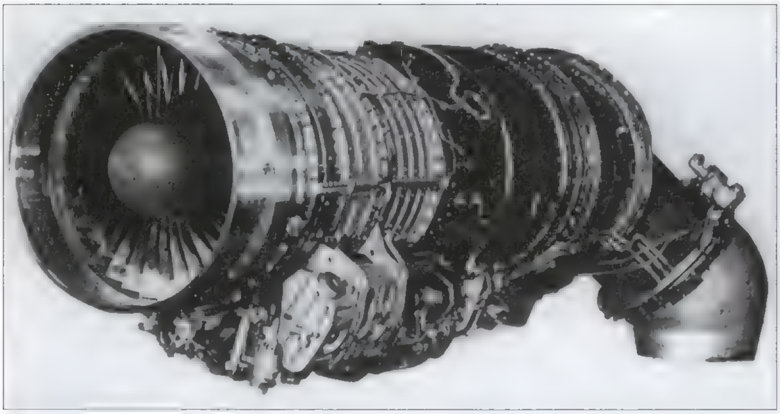
The Yak-38M is powered by two Kolesov (RKBM) RD-38 (*izdeliye* 38) lift engines rated at 3,250 kgp (7,160 lbst) apiece and a single Tumanskiy R28V-300 (*izdeliye* 59) lift/cruise engine (a version of the R27V-300) rated at 6,700 kgp (14,770 lbst) in lift mode and 7,100 kgp (15,650 lbst) in cruise mode. The RD-38 is a derivative of the RD36-35FVR and is structurally similar; the dry weight is 231 kg (509 lb).

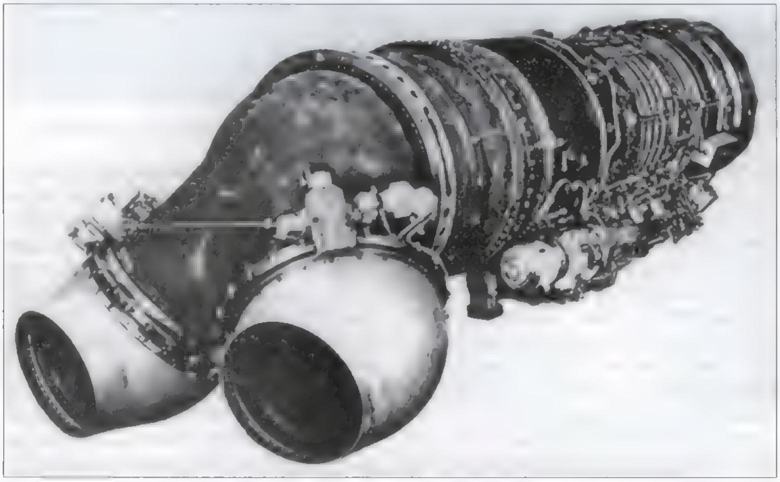
The lift engines are located in tandem in a bay aft of the cockpit (frames 10-14), breath-

The rear fuselage and tail unit of a late Yak-38 *sans suffixe* with anb Opushka-VM FDR on the tailcone.



Left: The early-model narrow-track main landing gear with straight struts.
Right: The wide-track main gear with 'dog-leg' struts typical of most Yak-38s.





Top: Front view of the Tumanskiy R27V-300 lift/cruise engine with the nozzles in vertical thrust position.
Above: Rear view of the same engine with the nozzles in cruise position.

ing through an intake with an aft-hinged door with spring-loaded suction relief doors and exhausting through ventral clamshell doors. The engines are inclined 10° forward (that is, the engine axes are at 80° to the direction of flight). The nozzles of the forward and rear lift engines are angled 15° aft and 15° forward respectively to form a common exhaust jet (that is, the thrust of the two lift-jets is vectored 25° aft and 5° forward respectively). The setting of the rear lift engine's nozzle was chosen after the Yak-38's Afghan evaluation, and the existing machines were modified accordingly.

To protect the lift engines and the surrounding structure from being overheated by the exhaust reflected from the ground or deck, a heat shield with apertures for the nozzles closes the lift engine bay from below. The heat shield is made of titanium sheet and attached to the fuselage by anchor nuts.

The lift engines' intake and exhaust doors are opened and start-up is effected by advancing a special control lever on the port cockpit console after starting up the main engine. Bleed air for lift engine starting is supplied only when the main engine nozzles are horizontal. The lift engines go to idling rpm; then, when the lift/cruise engine nozzles are set in accordance with the chosen operating mode, all three engines are operated together by a common throttle. The thrust of the lift engines and the main engine is varied automatically when the stick is moved back and forth in VTOL/hover and transition modes, assisting the reaction control system.

Control system: The Yak-38 has a combined flight control system. In cruise (forward flight) control around all three axes is provided by conventional controls, with the stick and rudder pedals being connected to the hydraulic actuators and control surfaces by duralumin or steel push-pull rods and bellcranks.

Directional control is provided by a one-piece rudder which is actuated manually (unpowered). Pitch (longitudinal) control is provided by one-piece elevators powered by a BU-105V hydraulic actuator. Roll control is provided by one-piece ailerons, also with BU-105V hydraulic actuators. The rudder, starboard elevator and starboard aileron incorporate an electromechanically actuated trim tabs. In forward flight the aircraft can be controlled either manually or by means of the SAU-36 automatic control system which includes a duplicated autopilot.

In VTOL, hover and transitional modes the Yak-36 utilises a reaction control system with control nozzles (puffers) under the fuselage nose, under the tailcone and at the wingtips. Air for the reaction control system is bled from the engine compressor. In these modes the aircraft is controlled by means of the SAU-36 automatic control system, making use of the RAU-107A servos (*roolevoy agregaht oopravleniya*).

The engine control system is linked to the longitudinal control channel. In VTOL, hover and transitional modes the ratio between the thrust of the lift engines and the main engine is altered automatically to enhance the aircraft's longitudinal control characteristics. During the transition from vertical flight to forward flight the lift/cruise engine nozzles are rotated incrementally from 0º (the vertical thrust position) to 25°, then to 45° and finally to 90°; the pilot selects the nozzle position by means of a switch as the aircraft accelerates. The lift engines' thrust is adjusted automatically in the process to maintain longitudinal balance.

Fuel system: On the Yak-38 *sans suffixe* all fuel is carried in two integral fuselage tanks – No. 1 (frames 14-23) and No. 2 (frames 31-33). The maximum standard fuel load is 2,750 kg (6,060 lb) – 2,160 kg (4,760 lb) in the No. 1 tank and 550 kg (1,210 lb) in the No. 2 tank. The fuel load in maximum-fuel configuration is 2,900 kg (6,390 lb), which is broken down as 2,260 kg (4,980 lb) and 640 kg (1,410 lb) respectively.

The Yak-38M has provisions for carrying two drop tanks on the inboard pylons, increasing the fuel load by 800 kg (1,760 lb).

The fuel system includes two fuel accumulators ensuring uninterrupted fuel delivery to the main engine in zero-G and negative-G conditions arising during combat manoeuvres. The fuel accumulators are located in the No. 1 tank.

The TPR1-9 fuel management system (FMS) automatically sequences the fuel tank usage to maintain the CG position. Manual fuel sequencing is possible if the automatic system fails.

The Yak-38 has single-point pressure refuelling. Fuel grades used are Russian T-1, TS-1, T-2, RT or T-7P.

Above: The semi-recessed starboard nozzle of the main engine, with a heat shield aft of it. Right: The open lift engine air intake of a derelict Yak-38M.

Hydraulics: Three separate hydraulic systems (main power system, actuator system and back-up power system).

The *main power system* has an NP-72M or NP-72MV plunger-type pump driven off the lift/cruise engine's accessory gearbox. It operates the aileron and elevator actuators, nosewheel steering mechanism and wing folding mechanisms.

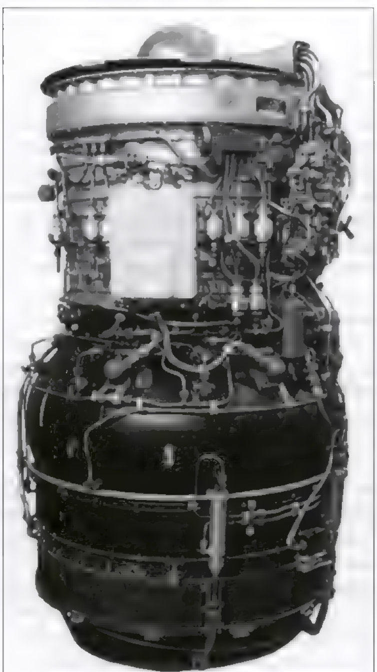
The *actuator system* operates the landing gear, flaps, lift engine intake and exhaust doors, and reaction control system air valves (all in normal mode), as well as the lift engine starting air cocks and forward reaction control puffer.

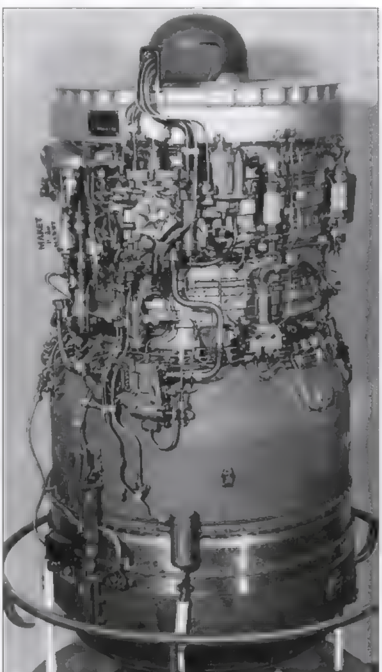
The *back-up power system* operates the aileron and elevator actuators if the main system fails and is activated automatically or manually.

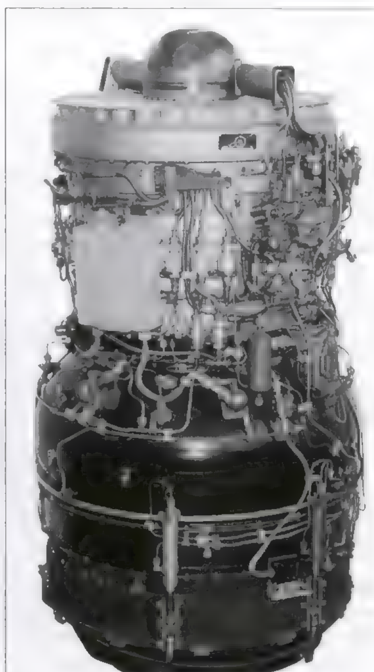
The main power system uses AMG-10 oil-type hydraulic fluid (*aviatsi**on**noye **mahs**lo ghidrav**lich**eskoye*) and features a hydraulic tank. The other two systems use fuel as the working fluid; the fuel is tapped from the main engine's fuel line. If the main power system fails, the back-up power system is automatically enabled and the actuator system is disabled; the functions of the latter are then taken over by the pneumatic system.

Pneumatic system: Two separate pneumatic systems (emergency and back-up). The *emergency system* serves for emergency extension of the landing gear and flaps, emergency operation of the lift engine intake and exhaust doors and reaction control system air valves. It is also responsible for normal operation of the wheel brakes and brake parachute deployment and release. The *back-up system* serves for wheel braking and brake parachute deployment in emergency mode.

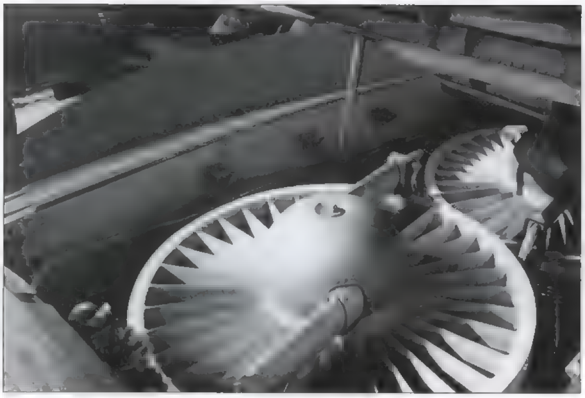
Electrics: Main 27 V DC power is supplied by an 18-kilowatt GSR-ST-18/70KIS engine-driven starter-generator, with backup DC power provided by two 15STsS-52B silver-zinc batteries. 36 V/400 Hz AC for the autopilot, navigation systems and flight instruments supplied by a 16-kVA GT-16PCh8D stable-frequency three-phase AC generator (*ghener**ah**tor tryokh**fahz**nyy postoy**an**noy chasto**ty***) and a PT-500TsS AC converter (*preobrazo**vah**tel' tryokh**fahz**nyy*). 115 V/400 Hz AC supplied by a PO-750A single-phase AC converters (preobrazo**vah**tel' odno**fahz**nyy). A ground power receptacle is provided on the port side.







The lift engines used on the Yak-38 family. Left to right: the RD36-35FV, the RD36-35FVR and the RD-38.



Above: The inlets of the RD36-35FVR lift engines.
Right: The fuselage of the VM-4 prototype is cut away in the area of the lift engines, showing how they are inclined forward.

Air conditioning and pressurisation system: The ventilation-type cockpit is pressurised by air bled from the lift/cruise engine to ensure proper working conditions for the pilot at high altitude. The canopy is sealed by an inflatable rubber hose running around the perimeter which is pressurised to 1.8-2.5 kg/cm² (25.7-35.7 psi).

Cockpit air temperature is maintained automatically at a preset value. Cockpit air pressure is governed by an automatic pressure regulator.

Oxygen system: The oxygen system supplies oxygen to the pilot throughout the flight, regardless if the cockpit is pressurised or not. In the event of depressurisation at flight levels above 8,000 m (26,250 ft), pure oxygen is supplied to the pilot's face mask.

The oxygen system consists of a main (on-board) system located in the cockpit and an emergency system in the ejection seat. The main system comprises a pair of 2-litre (0.44 Imp gal) bottles with gaseous form oxygen charged to 150 kg/cm² (2,205 psi), a charging connector and pipelines, a KP-52M breathing apparatus (*kislorodnyy pribor*) and a KM-34 oxygen mask (*kislorodnaya maska*) that goes with the ZSh-5A flying helmet.

The ejection seat features a KP-27M emergency breathing apparatus intended to supply the pilot with oxygen during the ejection sequence at high altitude and subsequent descent.

Avionics and equipment: The Yak-38 is equipped for IMC/VMC day and night shipboard and shore-based operations.

Navigation and piloting equipment: The Yak-38 has an SAU-4 automatic control system including an autopilot. The navigation/piloting equipment further includes an RSBN-36 *Kvadraht* (Square) short-range radio navigation/approach system (*rahdiotekhnicheskaya sistema blizhney navigahtsii* – SHORAN) with flush antennas built into the fin (early aircraft up to and including c/n 797786...502273 (f/n 0403) had the Kvadrat-D version, which was replaced by the Kvadrat-N from c/n 797786...502307 (f/n 0503) onwards). The Yak-38 is also fitted with an IKV-2 inertial attitude and heading reference system (*inertsionnaya koorsovertikahl'*), an NKV-2 vertical gyro, an MRP-56P marker beacon receiver, an RV-5 low-range radio altimeter working in the 0-750 m (0-2,460 ft) altitude range, an ARK-15 automatic direction finder and an SOS limiter system computes the maximum permissible airspeed in the current circumstances.

The flight instrumentation includes a KPP-1273-SI flight director (*komahndnopilotazhnyy pribor*), a PNP-72-6M artificial horizon (*plahnovyy navigatsionnyy pribor*), a KUS-1250 combined airspeed indicator (*kombineerovannyy ookazahtel' skorosti*), a VD-20 two-needle barometric altimeter (*vysotomer dvookhstrelochnyy*) and a DA-200P vertical speed indicator. The instrument panel also features a full set of engine instruments and systems gauges. The pitots serving the barometric instruments are located under the extreme nose.

Targeting equipment: The Yak-38 has an ASP-PFD-21 optical sight (which was to be replaced by an ASP-17BMTs computing sight) and a Del'ta-NG2 command line-of-sight guidance system for working with the Kh-23 and Kh-25MR missiles.

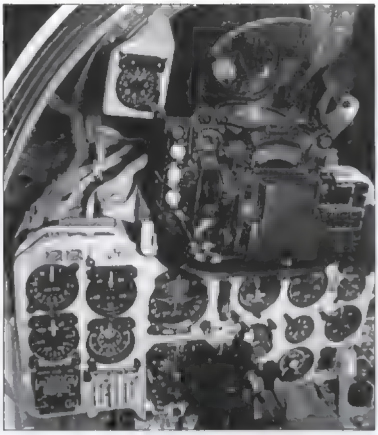
Communications equipment: For air-to-ground (air-to-ship) communications the Yak-38 has an R-860-1 Mod. G or R-863 radio with a blade aerial on top of the centre fuselage. The R-863 is a metre- and decimetre-waveband HF command radio designed for line-of-sight communication; it has 9,200 channels, including 20 pre-tuned ones. The R-864 VHF transceiver has a maximum transmission/reception range of 1,000 km (621 miles) and a frequency range of 2,000-17,999 kHz, including 10 pre-tuned frequencies. An SPU-9 intercom (*samolyotnoye peregovornoye oostroystvo*) is provided for communication with the ground crew (or deck crew).

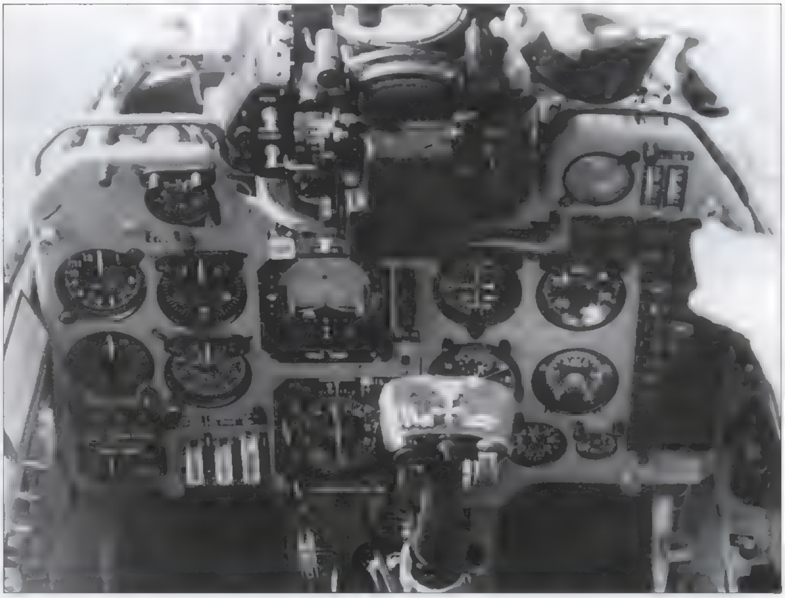
IFF system: SRO-2M Khrom IFF transponder (*izdeliye* 023), with characteristic triple rod aerials ahead of the cockpit canopy and under the tailcone.

ECM/ESM equipment: The Yak-38 has an SPO-2 Sirena-3M radar homing and warning system (RHAWS) and a *Seeren'-I* (Lilac) or *Gvozdika* (Carnation) active jammer.

Data recording equipment: Early-production aircraft had the Tester-UZL flight data recorder capturing 50 parameters in vertical, horizontal and transitional flight modes. The FDR is switched on automatically when the lift/cruise engine starting button is pushed and switched off only when electric power is cut. The FDR was housed inside the fuselage; however, in the event of an accident over water, recovering the FDR for accident investigation purposes proved difficult or even impossible. Therefore, from Yak-38 *sans suffixe* c/n 797786...97677 onwards (and from Yak-38U c/n 797776...54170 onwards) the Tester-UZL was replaced with the Opushka-VM FDR. This was housed in a buoyant and crashworthy container attached to the tailcone which would separate from the airframe and float to the surface if the aircraft sank; to facilitate recovery the floating FDR was equipped with a beacon whose signals would be picked up by the search and rescue crew.

Armament: The Yak-38 *sans suffixe* (Yak-36M) and Yak-38M are able to attack ground targets and surface vessels in day and night conditions. In case of need it can also engage aerial targets in daylight conditions. All weapons are carried under the wings on four BD3-60-23F1 pylons, each capable of carrying all types of external stores up to 500 kg (1,100 lb) calibre. The maximum ordnance is 1,000 kg (2,205 lb).





Above: The instrument panel of a typical Yak-38 dominated by an ASP-PFD-21 sight.

Right: The instrument panel of an early Yak-36M. The different instrument fit is plainly visible.

Cannon armament: With the exception of the initial production aircraft, the Yak-38 can be fitted with a VSPU-36 conformal cannon pod (*vneshnyaya syomnaya pushechnaya oostanovka* – detachable external cannon installation) housing a 23-mm (.90 calibre) Gryazev/Shipunov GSh-23 twin-barrel cannon with 160 rounds. This can be used against aerial and surface targets alike. Rate of fire is 3,400 rpm.

Additionally, up to four UPK-23-250 cannon pods, each housing a GSh-23 cannon with 250 rounds, can be carried under the wings.

Air-to-air missiles: For self-defence, Vympel R-60M (AA-8 *Aphid*) short-range AAMs can be carried on APU-60-1 missile rails (*aviatsionnoye pooskovoye oostroystvo* – aircraft-mounted launcher).

Air-to-surface missiles: Two Zvezda Kh-23M (*izdeliye* 68) or Zvezda Kh-25MR (*izdeliye* 69) missiles can be carried on APU-68 launch rails. The ASMs have command line-of-sight radio guidance are used with the podded Del'ta-NG2 guidance system.

Unguided air-to-surface weapons: The Yak-38 is able to carry the following types of weapons:

• 16-round UB-16-57UMP rocket pods and 32-round UB-32A or UB-32M rocket pods holding 57-mm (2.24-in) S-5 folding-fin aircraft rockets with various warheads;

• 20-round B8M-1 rocket pods holding 80-mm (3.15-in) S-8 FFARs with various warheads;

• 240-mm (9.44-in) S-24B heavy unguided rockets on PU-12-40 launchers;

• 50-kg (110-lb) P-50Sh high-explosive bombs, 120-kg (265-lb) OFAB-100-120 and OFAB-100NV HE/fragmentation bombs, 270-kg (595-lb) OFAB-250-270 and OFAB-250M554 HE/fragmentation bombs, 230-kg (507-lb) FAB-250-230 and 250-kg (551-lb) HE bombs;

• RBK-250 GPAB-2.5M, RBK-500 ZAB-2.5SM and RBK-500 ShOAB-0.5M cluster bombs (*rahzovaya bombovaya kasseta*) with HE, incendiary or fragmentation bomblets;

• ZB-500 napalm tanks;

• RN-28, RN-40 and RN-41 tactical nuclear bombs.

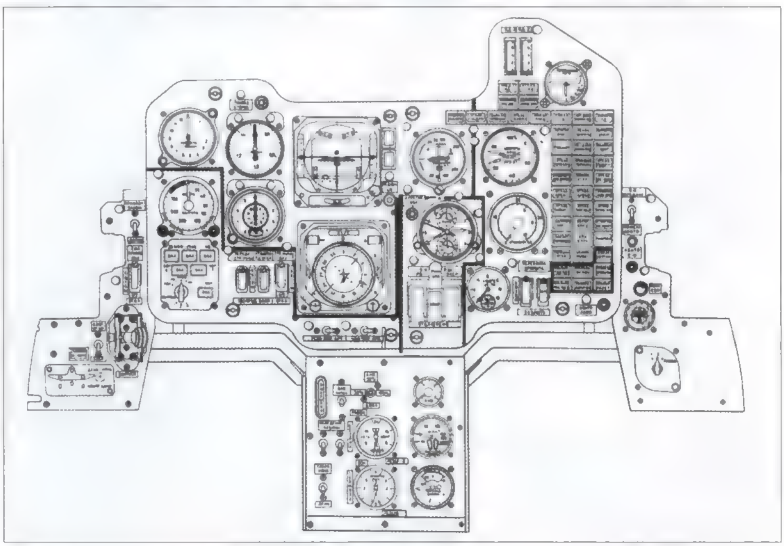
Other external stores: The Yak-38 can be outfitted with K-513D (RR8311-100) air sampling pods for nuclear/biological/chemical (NBC) reconnaissance. The Yak-38M is able to carry two 500-litre (110 Imp gal) drop tanks.

On a mission involving vertical take-off, the following payload combinations are possible:

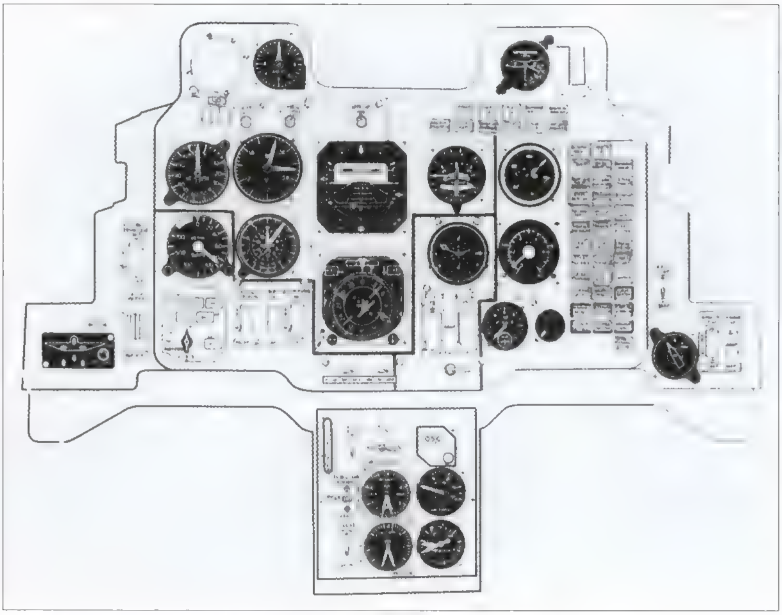
• two R-60M AAMs on the outboard pylons;

• two Kh-23M ASMs on the outboard pylons and a Del'ta-NG2 guidance system pod on the port inboard pylon;

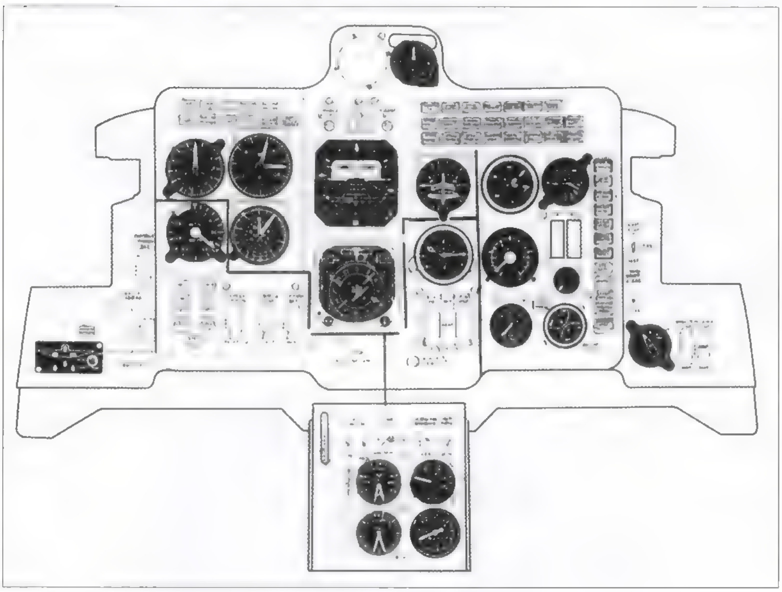
• two UB-32A-73 rocket pods outboard and two UB-16-57UMP-73 rocket pods inboard with a total of 96 S-5K1 FFARs with shaped-charge armour-piercing warheads or S-5M1 FFARs with HE/fragmentation warheads;



The main instrument panel of the single-seat Yak-38.



Above: The instrument panel of the front (trainee's) cockpit of the Yak-38U.



The instrument panel of the rear (instructor's) cockpit of the Yak-38U.

• two B8M-1 rocket pods on the outboard pylons with a total of 40 S-8V or S-8M FFARs;

• two S-24B or S-24BNK rockets on the outboard pylons;

• three FAB-100 bombs on MBD2-67U multiple ejector racks (MERs) on each outboard pylon;

• one FAB-100 bomb on each pylon;

• two FAB-250 bombs outboard and two FAB-100 bombs inboard;

• one RN-28, RN-40 or RN-41 nuclear bomb on the port outboard pylon, with one FAB-250 on the starboard outboard pylon and one FAB-100 on the starboard inboard pylon to act as counterweights;

• two ZB-500 napalm tanks on the outboard pylons;

• two UPK-23-250 cannon pods on the outboard pylons.

With the VSPU-36 cannon pod fitted under the fuselage, the following payload options are possible (this implies a short rolling take-off):

• two R-60M AAMs on the outboard pylons;

• two Kh-23M ASMs on the outboard pylons and a Del'ta-NG2 guidance system pod on the port inboard pylon;

• two UB-32A-73 rocket pods outboard and two UB-16-57UMP-73 pods inboard with a total of 96 S-5K1 or S-5M1 FFARs;

• two B8M-1 rocket pods on the outboard pylons with a total of 40 S-8V or S-8M FFARs;

• four S-24B or S-24BNK rockets on the outboard pylons;

• five FAB-100 bombs on MERs on each outboard pylon;

• one RN-28, RN-40 or RN-41 nuclear bomb on the port outboard pylon, with one FAB-250 on the starboard outboard pylon and one FAB-100 on the starboard inboard pylon to act as counterweights;

• two ZB-500 napalm tanks outboard and two FAB-250 bombs inboard;

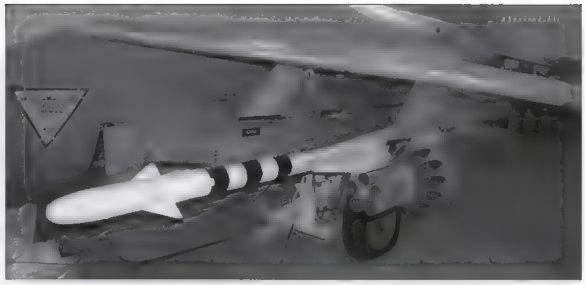
• four UPK-23-250 cannon pods.

The ASP-PFD-21 optical sight is used for aiming the rockets, AAMs and cannons, as well as for bomb-aiming during level and dive-bombing attacks. The Kh-23M missile is controlled by means of a mini-joystick on the aircraft's control stick; the pilot keeps the missile on course to the target, using a tracer on the missile's tail as a visual reference. Launch is possible at up to 8 km (5 miles) range within a wide range of speeds and altitudes.

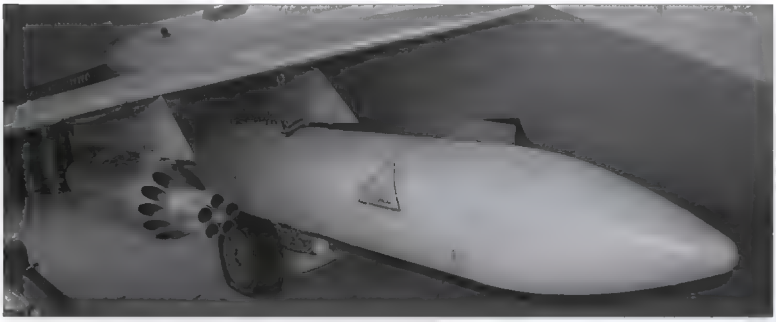
The gunnery, rocket/missile launch and bomb delivery results are recorded by an SSh-45-100-OS gun camera.

Emergency escape system and pilot gear: The crew rescue system is designed to provide safe ejection in the event of an emergency arising during vertical take-off or landing, in the hover, in transitional flight modes (including the take-off and landing run) and in cruise flight over land or water. Ejection is initiated automatically if the aircraft's pitch or bank angles or pitch and roll rates exceed preset limits. The values of these parameters are supplied to the crew rescue system's processor by the flight control system and the crew rescue system's own sensors. The automatic ejection feature is disabled when the lift/cruise engine nozzles are rotated aft past 67° from the vertical.

The first ten production Yak-38s (up to and including c/n 797786...502375) were equipped with the Yakovlev KYa-1M ejection seat featuring the PS-Ya Srs 2 parachute system and with the SK-EM electric ejection system. From c/n 797786...502409 onwards the aircraft was fitted with a new rescue system comprising a Zvezda K-36VM zero-zero ejec-



Above: A UPK-23-250 cannon pod and an R-60M air-to-air missile under the wing of Yak-38M '88 Yellow' at Khodynka.
Right: A UB-16-57UMP-73 FFAR pod and a dummy R-60 AAM on an APU-60-1 launch rail under the wing of Yak-36M f/n 0201.



Above: The other wing of Yak-36M f/n 0201 with a 500-litre drop tank on the inboard pylon.
Right: A dummy Kh-23M air-to-surface missile under the wing of a Yak-36M.

tion seat with an NAZ-7M survival kit (*no**sim**yy ava**reey**nyy za**pahs*** – 'portable emergency kit') and a revised SK-EMP ejection system. The survival kit comprises an R-855UM Komar-2M (Mosquito) UHF radio, a PSN-1 one-man inflatable life raft (*plot spa**sah**tel'nyy nadoov**noy***), a food supply, camping gear, signal flares and a first-aid kit. It is attached to the parachute harness and separates from the seat concurrently with the pilot, hanging on a line slightly below the level of his feet.

The KYa-1M seat was activated manually in forward flight and automatically in vertical flight, hover and transitional flight modes as commanded by the SK-EM system. The seat was fired by a KSM-Ya1M ejection gun (*kombi**neer**ovannyy stre**lya**yushchiy mekha**nizm***).

The K-36VM was activated manually in forward flight and automatically in vertical flight, hover and transitional flight modes (though manual actuation is also possible in these modes). It is fired by a KSMU-36VM ejection gun. The K-36VM guarantees safe ejection at speeds of 140-1,100 km/h (87-683 mph) at all normal operational altitudes, providing the canopy is jettisoned before ejection and the pilot wears a ZSh-5A helmet. Ejection through the canopy is possible at up to 500 km/h (310 mph); the minimum safe altitude in this case is 40 m (130 ft). Ejection at sea level is possible at up to 950 km/h (590 mph).

Canopy jettisoning is disabled when the lift engines' air intake is open. Depending on the ejection speed, the pilot's stabilising parachute and main parachute deploy with a delay or straight away.

Two versions of pilot gear are used. For overwater operations the pilot is required to wear the VMSK-4 maritime rescue outfit (*vy**sot**nyy mor**skoy** spa**sah**tel'nyy kom**plekt***) together with the PPK-1UK G-suit (*protivo-pere**groo**zochnyy kos**tyum***). The VMSK-4

Above: The Yakovlev KYa-1M ejection seat fitted to early Yak-36Ms.
Right: The VMSK-4 naval pilot's rescue outfit, complete with ZSh-5A helmet.

comprises the VZK-2 waterproof overall (*vodoza**shchit**nyy kombine**zon***) and the TZK-2 waterproof overall (*teploza**shchit**nyy kombine**zon***) preventing hypothermia in the event of a splashdown in cold water. For operations over land the VK-3 ventilated suit (*ventil**ee**ruyemyy kombine**zon***) is used together with the PPK-1UK G-suit. In both cases the pilot wears a ZSh-5A protective helmet (*za**sh**chitnyy shlem*) with a KM-34 oxygen mask and the ASP-74 automatic beacon guiding search and rescue teams to the site of the ejection (*avtomat**i**cheskaya sis**te**ma po**i**ska* – automatic search system).

* * *

The Yak-38U conversion trainer has an extended and drooped forward fuselage incorporating tandem cockpits. The latter are enclosed by a common canopy with a fixed windshield and individual sections opening manually to starboard; there is a fixed glazed canopy portion between them. To ensure adequate stability and control the trainer has a longer rear fuselage and a longer-span horizontal tail.

The trainer features full dual controls. The instructor can override the trainee in controlling the landing gear, flaps, powerplant and SAU-36 automatic control system. He also enjoys priority in initiating ejection (that is, he can eject both himself and the trainee in an emergency) and in transmitting radio messages during air-to-ground (air-to-ship) communication.

The Yak-38U features modified Zvezda K-36VMU ejection seats working with the SK-EM electric ejection system. For the first time in the Soviet Union, the crew escape system provided for simultaneous enforced ejection in vertical flight/hover mode with diverging seat trajectories to prevent the pilots from colliding. In the event of manually controlled ejection the delay between the two pilots' ejection is 0.6 seconds.

Early Yak-38Us had permanently installed wings; from c/n 7977762038454 onwards the wings were made detachable. Early aircraft had RD36-35FV lift engines which were replaced by the uprated RD36-35FVR model later on. Ventral recirculation dams installed between frames 14-29 were added from c/n 797776…20346 onwards.

The trainer has a suitably modified SAU-36U automatic control system and fully duplicated flight and engine instruments and systems gauges. Aircraft up to and including c/n …02273 had the Kvadrat-D version of the RSBN-36 SHORAN, which was replaced by the Kvadrat-N from c/n …02307 onwards. The communications system features an SPU-9 intercom.

Yak-36M/Yak-38 family specifications

	Yak-36M	**Yak-38**	**Yak-38M**	**Yak-38U**
Length overall, including pitot	16.37 m (53 ft 8$\frac{31}{64}$ in)	16.37 m (53 ft 8$\frac{31}{64}$ in)	16.37 m (53 ft 8$\frac{31}{64}$ in)	17.76 m (58 ft 3$\frac{7}{32}$ in)
Wing span:				
wings unfolded	7.022 m (7 ft 0$\frac{29}{64}$ in)	7.022 m (7 ft 0$\frac{29}{64}$ in)*	n.a.	7.022 m (7 ft 0$\frac{29}{64}$ in)
wings folded	4.45 m (14 ft 7$\frac{13}{64}$ in)	4.45 m (14 ft 7$\frac{13}{64}$ in)	4.45 m (14 ft 7$\frac{13}{64}$ in)	4.45 m (14 ft 7$\frac{13}{64}$ in)
Height on ground	4.25 m (13 ft 11$\frac{21}{64}$ in)	4.25 m (13 ft 11$\frac{21}{64}$ in)	4.25 m (13 ft 11$\frac{21}{64}$ in)	4.25 m (13 ft 11$\frac{21}{64}$ in)
Net wing area, m^2 (sq ft)	18.41 (197.95)	18.41 (197.95)	18.41 (197.95)	18.41 (197.95)
Landing gear track	n.a.	2.75 m (9 ft 0$\frac{17}{64}$ in)	n.a.	2.75 m (9 ft 0$\frac{17}{64}$ in)
Landing gear wheelbase	n.a.	6.06 m (19 ft 10$\frac{37}{64}$ in)	n.a.	6.24 m (20 ft 5$\frac{21}{32}$ in)
Empty operating weight, kg (lb)	7,020 (15,480)	7,020 (15,480)	7,500 (16,530) †	8,390 (18,500)
Take-off weight, kg (lb):				
VTOL mode	10,300 (22,710)	10,300 (22,710)	10,800 (23,810)	10,000 (22,045)
STOL mode	n.a.	11,300 (24,910)	11,800 (26,020)	n.a.
Fuel load, kg (lb):				
internal	2,750 (6,060)	2,750 (6,060)	2,750 (6,060)	2,750 (6,060)
external	–	–	800 (1,760)	–
Ordnance load, kg (lb):				
VTOL mode	n.a.	1,000 (2,205)	1,000 (2,205)	n.a.
STOL mode	n.a.	1,500 (3,310)	2,000 (4,410)	n.a.
G limit	6.0	6.0	6.0	n.a.
Maximum speed, km/h (mph):				
at sea level	1,210 (751)	1,210 (751)	1,210 (751)	850 (528)
at high altitude	1,100 (683)	n.a.	n.a.	n.a.
Service ceiling, m (ft)	11,300 (37,070)	11,300 (37,070)	12,000 (39,370)	5,000 (16,400)
Combat radius at low altitude in VTOL mode, km (miles)	195 (121)	195 (121)	n.a.	n.a.

* some sources give a wing span of 7.32 m (24 ft 0$\frac{3}{16}$ in)
† some sources give a weight of 7,484 kg (16,499 lb)

Notes:
1. All data are for ISA conditions
2. The Yak-36M's effective range in ISA conditions with no wind, in VTOL mode and with 7% fuel reserves is as follows. At low altitude (200 m/660 ft) and 850 km/h (528 mph) the range is 370 km (229 miles) with six OFAB-100-120 bombs on MBD2-67U MERs, 460 km (285 miles) with two Kh-23M missiles on APU-68 launch rails, 500 km (310 miles) with two R-60 missiles on APU-60-1 launch rails and 530 km (329 miles) in 'clean' condition. At high altitude (10,000 m/32,810 ft) and 950 km/h (590 mph) the range is 730 km (453 miles), 860 km (534 miles), 1,000 km (621 miles) and 1,100 km (683 miles) respectively. The range is given assuming that the ordnance is expended in the middle of the sortie.

Above the Oceans

In 1974 the first service flying group comprising ten pilots was formed at the AVMF flight training facility at Novofyodorovka AB in Saki. In the summer of that year the pilots, together with the group of maintenance engineers and technicians, started studying the Yak-36M theoretically. The flight and ground crews went to the Saratov aircraft factory to familiarise themselves with the airframe; they studied the powerplant in Moscow and Rybinsk, where the main and lift engines respectively were being manufactured, while the crew rescue system was studied at the Zvezda enterprise in Lyubertsy, Moscow Region, and at the Yakovlev OKB.

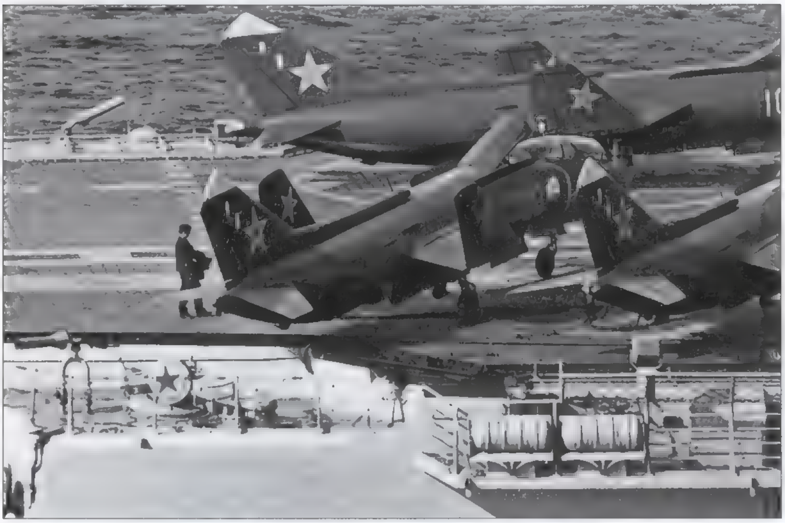
The flight training at Saki was backed up by the construction of special pads for hovering flight, take-off and landing; these were supplemented by engine run sites and a maintenance area. Later an additional runway paved with metal was built alongside the main runway. Measuring 320 m (1,050 ft) in length, it featured special markings simulating the contour of the runway on the deck of the Type 1143 aircraft carrier and was intended for short rolling take-offs. Furthermore, the maintenance and repair services were duly prepared for conducting routine maintenance and other jobs on the new aviation hardware.

The chiefs of GNIKI VVS and test pilots recommended that the candidates for conversion to the Yak-36M be selected among the service pilots flying MiG-21 fighters and Su-7 fighter-bombers. They were to start their training on the Ka-25 helicopter, whereupon they would proceed to mastering the VTOL machines.

The AVMF basically followed this recommendation, albeit with a few exceptions. Among the pilots selected for the conversion training were also those who had flown other

Above: SNS *Kiev*, the first of the Type 1143 aircraft carriers where the Yak-38s were based. Two Yak-38s and four Ka-25PL ASW helicopters are on the deck. Right and above right: The second ship in the series, SNS *Minsk*, going full steam ahead. Note the gun and the missile launch tubes on the foredeck.

Above: The 'flight line' on the deck of the *Kiev*, with four Yak-38s on the launch pads marked by circles. A practice scramble is depicted here.



Above: Yak-38U '08 Yellow' shares the deck of SNS *Kiev* with two single-seat Yak-38s. One of them ('10 Yellow') has an Opushka-VM FDR on the tailcone.

Yak-38 '14 Yellow' comes in to land on the *Kiev* as she ploughs through the waves of the Mediterranean.

types of aircraft, as well as helicopter pilots. However, later they showed no enthusiasm for flying the Yak-36M and were relieved from the conversion training at their own request.

In March 1975 the Naval Aviation pilots Fyodor G. Matkovskiy, Yuriy N. Kozlov and G. L. Kovalyov started their conversion training on the Yak-36M at the GNIKI VVS test centre in Akhtoobinsk. They were trained by the military test pilots Vladilen P. Khomyakov and Viktor V. Vasenkov and the LII test pilot Oleg G. Kononenko. It was Col. Yuriy Kozlov, chief inspector pilot of the AVMF, who performed the first flight in CTOL mode on 3rd March of that year. On 19th August Fyodor Matkovskiy became the first to perform a 'full profile' flight involving vertical take-off and landing. On 6th April 1976 he, again as the first among service pilots, performed a landing on the deck of the carrier SNS *Kiev* (the ship being stationary). Sadly, on 15th April that year Matkovskiy crashed fatally while flying a MiG-21U combat trainer.

In late 1975 and early 1976 the first batch of production Yak-36Ms, comprising six machines, arrived at Saki to be used by service pilots of the Naval Aviation for conversion training and mastering the new hardware. The first flight operations day was 16th December, three machines being flown. The flying was not uneventful. On 17th January 1976 Matkovskiy and Kovalyov took off in the prototype Yak-36MU two-seat-trainer ('05 Yellow'), the task being to perform a hovering flight at an altitude not exceeding 5 m (16 ft). In accordance with the prescriptions of the flight manual, in such cases the nosewheel was to be unlocked and the ejection seats inactive. During the hover they became aware of the aircraft's abnormal behaviour in pitch control. Displaying courage and professional skill, they performed a 'full profile' flight and performed an extremely difficult vertical landing, which was the only landing mode possible under those circumstances. The flight manual expressly forbade performing a conventional rolling landing with the nosewheel unlocked, and the ejection seats were not armed, thus making an ejection impossible.

The flight lasted 14 minutes. The pilots were rewarded by an official expression of gratitude from the Soviet Navy Commander-in-Chief and received valuable gifts (naval binoculars) – which, however, never reached the pilots, being misappropriated by someone along the chain of command. This incident became an object of a thorough investigation (voice recordings and flight data recorder tapes were studied). Upon visual inspection of the pitch control circuit G. A. Matveyev, the engineer in charge of the entire expedition, discovered the fact that the shutter of the rear reaction control puffer had been rotated 180° by mistake during routine maintenance; as a

result, the puffer's reaction to control inputs was just the opposite of what was required.

In May 1976 eleven service pilots completed their training; six of them were qualified for performing landings on a ship's deck. In July of the same year the production aircraft, pilots and maintenance personnel were moved to the carrier (or 'heavy aircraft-carrying cruiser') SNS *Kiev*. Her carrier wing was the 279th OKShAP (*otdel'nyy korabel'nyy shtoormovoy aviapolk* – Independent Shipboard Attack Air Regiment).

To expedite and facilitate the training of service pilots, OKB-115 had developed a special simulator called ***Irtysh*** (the name of a Siberian river); a prototype example of this simulator was commissioned at Novofyodorovka AB, Saki, on 1st June 1977. By 10th October of the same year 242 'flying hours' were logged on it. The Irtysh simulator helped tackle the following tasks associated with pilot training:

• performing the pre-flight check of the cockpit equipment of the Yak-36M and preparing it for flight;

• performing the engine start-up preparation procedure, starting the engines, 'test-running' them in the carrier deck take-off mode, starting the engines 'in the air';

• taxiing and performing a vertical take-off and a short rolling take-off;

• calculating the landing approach and performing a vertical landing or a landing with a short run;

• taking off from, and landing on, a moving ship's deck with the ship rolling within 6°, pitching within 3° and the deck moving up and down ±2 m (6.5 ft);

• piloting the aircraft instrumentally with a simulated line of horizon;

• checking the pilot's actions in abnormal flight situations.

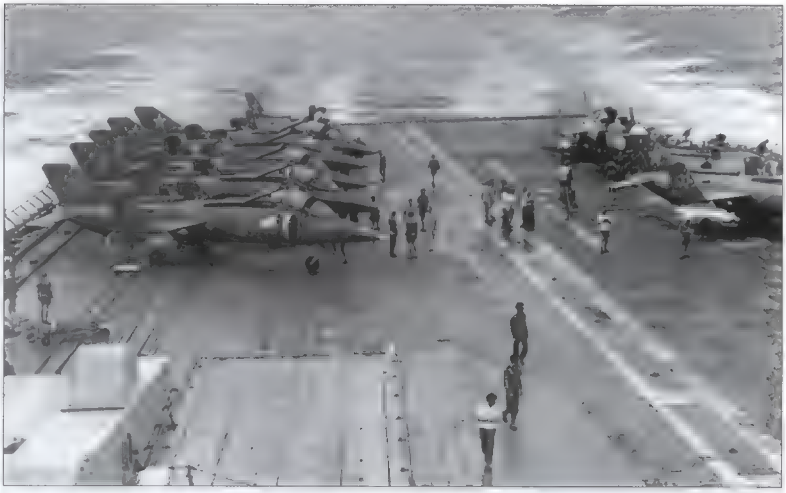
The simulator was used to represent day and night conditions with the ship visually observable, the night-time take-off facilities and the line of horizon. The device was particularly useful during the initial stage of the training, helping the pilot to acquire the right habits of distributing and switching his attention and to master the sequence of operations with the cockpit equipment.

Later, the series-produced simulators which had passed State acceptance trials were supplied to the main locations where Yak-38s were deployed – Severomorsk-3, Nikolayev and Vladivostok.

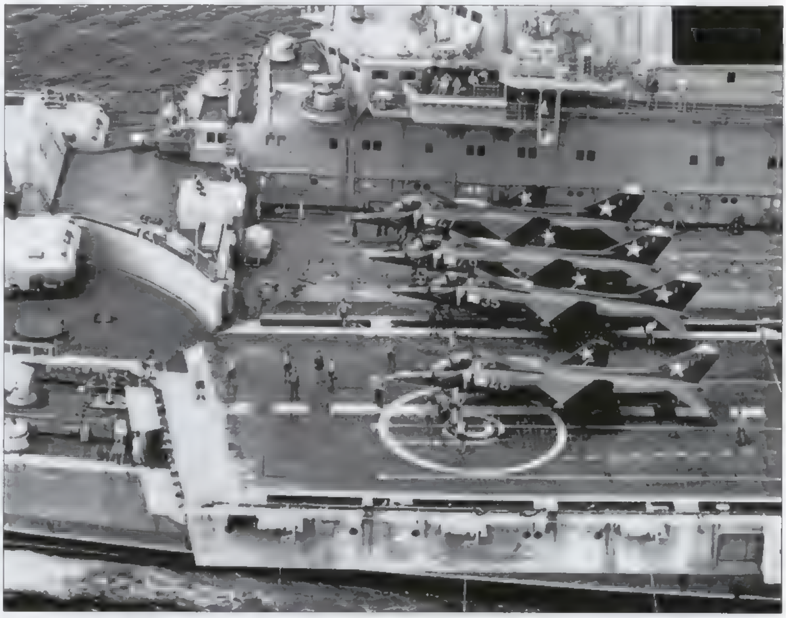
Getting somewhat ahead of our story, it should be noted that by 1977 as many as 34 pilots had been trained to fly the Yak-38, joined by a further 26 in 1978; by the end of 1970 nearly 60 service pilots had qualified for carrier operations.

In early July 1976, before the *Kiev*'s Northern cruise, service pilots of the AVMF gave a demonstration of the Yak-36M's operation from the ship's deck to the Navy's command. Between 16th July and 10th August the carrier made a trip to the High North, with five Yak-36Ms and one Yak-36MU on board; this involved a circuitous route via the Mediterranean. On 18th July SNS *Kiev* passed the Bosporus Strait and the Aegean Sea, entering the Mediterranean. The unexpected emergence of the Soviet aircraft carrier created a sensation. The *Kiev* was immediately 'attacked' by US Navy Lockheed P-3 Orions, Royal Navy BAe Nimrods and Royal Air Force BAe Canberras anxious to produce the first photos of the ship and her aircraft. The reconnaissance aircraft were particularly active at the moments when the Yaks were lifted to the deck.

Flight operations commenced when the Soviet carrier was in the vicinity of the island of Crete. An extremely obtrusive Orion came excessively close to the ship, jeopardising the safety of the flights which were to take place that day. Fyodor G. Matkovskiy had to 'scare it away'. Accelerating, the Yak-36M climbed and made a vigorous turn in the direction of the unwelcome guest, making it clear that its presence was undesirable. The Orion



Above: The rear deck of SNS *Minsk*, with eight Yak-38s visible; two of them are armed with Kh-23 missiles. The stern deck lift is in the foreground.



Four Yak-38s sit side by side at the front end of the *Minsk*'s flight deck. The launch pad marked 'C' (a Cyrillic 'S') is for a search-and-rescue helicopter.

Top: Two Yak-38s basking in the sun on the deck of SNS *Kiev* display their green undersides. '25 Yellow' shows obvious signs of recoding. Top right: Pilots clad in orange-coloured VMSK-4 outfits sprint toward their Yak-38s. Above: '33 Yellow' lifts off vertically, commencing another sortie. Right: The AK-90F ceramic tiles on the *Kiev*'s flight deck had to be replaced from time to time, creating 'mosaic patterns'.

changed course and went on accompanying the ship at a respectful distance.

During the flights in the vicinity of Crete a fire broke out in the rear fuselage of Matkovskiy's aircraft, '19 Yellow', as it was making a landing approach. Possibly the pilot was unaware of this, and when he climbed out of the cockpit, the deck hands had already tackled the situation on their own, without making use of the ship's fire-fighting equipment.

The cause of the fire was traced to a burst pipeline which supplied the hydraulic actuator turning the nozzles of the lift/cruise engine. The system used jet fuel as the working fluid. The rupture was due to insufficient strength of the duralumin piping; the strong vibration, especially in the vertical take-off and landing modes, was a contributing factor.

The Yak-38s based aboard SNS *Novorossiysk* had high tactical codes. It was standard operational procedure to keep the lift engine air intakes open when parked – in case of a scramble.

The situation that emerged was a royal mess. The carrier had just reached the open seas where she was expected to demonstrate the Soviet Union's power – and there you are! A fire on board the aircraft when the flights had barely commenced! The point was that the Yak-36s had to be grounded until the cause of the incident had been clarified and eliminated, but the task of putting on a show of power was still there... The situation was fraught with a complete failure to fulfil the mission, with all the repercussions to follow.

Urgent measures were taken. The duralumin piping was replaced by pipelines made of titanium; that solved the problem. In addition, as a further safeguard against the risk of compromising the show of 'combat power', it was decided urgently to deploy to the ship several production aircraft that were kept in reserve and had logged fairly many flying hours (the machines in question were primarily from the early batches, featuring the original narrow-track landing gear). For example, an aircraft coded '10 Yellow' (f/n 0102) was urgently repainted and redeployed to the *Kiev* where it flew ten sorties from the ship's deck. One more ploy was used: the aircraft were repeatedly repainted with new tactical codes to fool the Western observers into thinking there

The Soviet aircraft carriers were constantly shadowed and photographed by Western reconnaissance aircraft during their cruises. This is SNS *Minsk*; her Yak-38s had tactical codes in the medium range (30s, 40s and 50s). Note the Soviet coat-of-arms on the carrier's stern.

Here, at least five of the *Minsk*'s aircraft are being readied for the day's flying, with three more on standby duty. '53 Yellow' appears to have had a nose job (the nose was probably damaged and repaired).

Left: Seen from a shadowing NATO reconnaissance aircraft, two Yak-38s and a Ka-25 sit parked beside the island of SNS *Kiev*.

Below left: A rarely seen picture – two Yak-38s parked on the ship's deck are completely wrapped in tarpaulins. Note the bow deck lift on the left.

VTOL aircraft attrition statistics

	USA	UK	USSR
Total number of aircraft	110	105	45
Number of accidents	29	28	10
Number of aircraft lost	22	24	6
Causes:			
hardware failures	6	12	3
pilot error	21	3	6
other causes	2	9	1
Ejections	11	16	4
of these, successful	7	12	4
Pilots lost	10	9	none

were more aircraft aboard than there actually were. (Incidentally, a Yak-36M coded '10 Yellow' is preserved on a plinth at the North Fleet airbase in Severomorsk near Murmansk.)

In the course of the passage to the North seven flying shifts were held, the Yak-36Ms performing 45 sorties and logging a total of 22 flight hours. The flights were performed by the AVMF pilots Fyodor G. Matkovskiy, V. N. Ratnenko, V. F. Saranin, V. M. Svitochev, V. I. Kolisnichenko, V. I. Dmitrenko and V. I. Kuchuyev. On 10th August 1976 the ship arrived at her port of registry, Severomorsk.

The combat service of SNS *Kiev* commenced on 2nd January in the Mediterranean (that is, discounting the carrier's passage from Sevastopol' to Severomorsk which can be classed as service tests. The ship had a full complement of production aircraft which were flown by service pilots of the Naval Aviation. The *Kiev* left Severomorsk at 1100 hrs on 20th December 1977. On 30th December the first 10 flights were made in the Bay of Biscay. In the Mediterranean the number of flights within a flying shift could reach 18. A total of 112 flights were made during the cruise, including 26 hovering flights and ten live weapons training sorties. The flying personnel practised the piloting in the manoeuvring area, flights along designated routes, interceptions and attacks against aerial targets, attacks against surface ships from simple and complex manoeuvres.

One of the types of the pilots' combat training was gunnery and bombing practice against inflatable targets. A target of that kind was usually a cylinder made of rubberised fabric; when inflated it was 6 m (19 ft 8 in) long and 2 m (6 ft 6 in) in diameter. It could also have the shape of a doughnut with a diameter of up to 4 m (13 ft 1 in). Such targets were towed on a 800-m (2,620-ft) cable behind a ship. As a rule, they were destroyed in the first firing pass (at worst, in the second); the special team tasked with getting the targets ready had a hard time lowering new targets to the surface to cater in time for the pre-scheduled number of firing passes. Pilots Gusenkov, Mitin, Yedush, Kondratyev became real experts in flying attack missions.

The naval airmen strove to enhance the combat capabilities of the Yak-38. One of the means to that end was a group take-off of the VTOL aircraft. On 30th January 1978 three pairs of aircraft simultaneously launched from the ship for the first time. The interval between the pairs' take-off was three minutes, and the interval between the aircraft in a pair was 40-50 seconds.

SNS *Kiev* continued her service in the Mediterranean until February 1978 and then returned home to Severomorsk.

In March 1978 the training of service pilots for night flying commenced. To begin with, GNIKI VVS test pilot Colonel Khomyakov issued a licence for night flying to another GNIKI VVS pilot, Viktor V. Vasenkov; on 13 March such a licence was issued to G. L. Kovalyov, Commander of the 279th OKShAP. This took place aboard the *Kiev* which had come to Sevastopol' for routine repairs.

The Yak-38's serviceability rate

Year	1976	1977	1978	Total
Number of flights	758	2,711	5,126	8,595
Flight hours logged	304	796	1,522	2,622
Flight hours per 1 failure in flight	2 hrs 36 min	8 hrs 10 min	13 hrs	
Number of flights per 1 failure in flight	6	27	45	

As per 6th May 1978, the Soviet Navy had 45 operational VTOL aircraft in its inventory; at that point the UK had 105 such machines (Royal Air Force and Royal Navy Harriers) and the USA had 110 (US Marine Corps McDonnell Douglas AV-8 Harriers). A table on the opposite page provides statistics pertaining to incidents and accidents with these aircraft.

The next table provides statistics on the reliability of the Soviet VTOL aircraft for a three-year period.

On 15th December 1978, at 1000 hours, SNS *Kiev* left Severomorsk for her second long-range cruise. She was escorted by the cruisers SNS *Yumashev* and SNS *Smyshlyonnyy*. 26th December was the first flight operations day. Off the south-western coast of Scotland a French Navy frigate approached the *Kiev*. Prompted by the wish to have a better view of the Soviet aircraft carrier, she came within dangerously close range, and the *Kiev*'s captain decided to run the nosy visitor off. Pilot Ye. M. Alifanov took off in his Yak-38 and 'buzzed' the frigate, whereupon the latter moved away, but still did not leave the area and followed the *Kiev* doggedly.

In the course of the second cruise the Kiev's flying personnel performed 355 flights (training and combat practice flights), and on 19th January 1979 the ship's entire crew celebrated a 'jubilee': the regiment's Deputy CO N. P. Yedush performed the 100th carrier landing. Yedush's style of flying was confident and brave; in difficult circumstances he always displayed high skill and presence of mind.

On 15th March SNS *Kiev* passed the Strait of Gibraltar. On 28th March she returned to her port of registry.

Yak-38 '51 Yellow' looks rather rather forlorn, with missing panels and the undernose antenna askew.

The year of 1978 saw the commissioning of SNS *Minsk* – the second Type 1143 aircraft carrier, which was assigned to the Pacific Fleet, with the 311th OKShAP as her carrier wing. On 28th February 1979 a rendezvous between two Soviet carriers – *Minsk* and *Kiev* – took place off the coast of Libya. The US Navy's 6th Fleet witnessed the joint flights performed by five Yak-38s from both ships. On 14th March the ships 'went their separate ways'.

When SNS *Minsk* was in the Atlantic Ocean, on several occasions the Yak-38's lift engines would refuse to start during the preflight preparations due to a combination of high ambient temperature and high humidity. Urgent measures had to be taken to ensure a reliable start-up of the lift engines. It was decided to equip the aircraft with two 4-litre (0.88-Imp gal) oxygen bottles providing additional air feed to the engines during the start-up. This improvement was tested on the ground and in flight at Saki, and the final decision was taken proceeding from the results of these tests. After this, two sets of lift engines, oxygen bottles and parts required for the installation were shipped to the port of Aden, Yemen, where SNS *Minsk* was docked at that time. The new engines were installed in the two Yak-38s on which the lift engines were particularly reluctant to start up; the modification eliminated the problem completely.

On 7th June 1979 the personnel of SNS *Minsk* had their first 'acquaintance' with sharks. Lt. (Senior Grade) V. A. Perepechko and instructor Yu. Churilov were performing a check-up flight in a Yak-38U trainer coded '08 Yellow' (c/n 7977763713243, f/n 0203). An emergency arose when the aircraft was at a distance of 2.2 km (1.4 miles) from the ship, making a landing approach at a speed of 350 km/h (218 mph) and an altitude of 130 m (430

The Black Sea Fleet's Yak-38s make a sorry sight as they sit huddled together on the grass at Saki, never to fly again. Three of the at least 25 single-seaters wear the seldom seen grey colour scheme. All except one of the seven Yak-38U trainers are parked separately.

Above: *Sic transit gloria mundi*. Yak-38M '99 White' (white tactical codes are extremely rare for the type!) has been reduced to a stripped-out hulk at Saki.

Above: Grey-painted Yak-38M '63 Yellow' (c/n 7977824708489, f/n 0505), also derelict at Saki, wears seldom seen nose art – a cobra's head and Tom the cat from the MGM cartoon series *Tom and Jerry*!

ft). After the pilot had reported 'nozzle position vertical, reaction control puffers on' the aircraft entered a dive, not responding to the pilot's control inputs. Four to five seconds after the transition to vertical thrust mode the pilots ejected to safety, the aircraft plunging into the sea and sinking in 3,100 m (10,170 ft) of water. There were two possible causes of the accident: either both lift engines had failed to spool up from flight idle to full power, or one of the engines (most probably the forward one) had cut. Once in the water, the pilots made use of a special dye-stuff intended for repelling the sharks. The water around them became orange-tinted, but fairly quickly the tinted spot was swept away by the waves, and the pilots found themselves surrounded by the deadly predators. It took some time before the Ka-25PS SAR helicopter sent to their rescue from the carrier managed to 'fish them out'.

The cruise lasted 130 days. SNS *Minsk* paid visits to Angola (Luanda), Mozambique, Mauritius (Port-Louis), the island of Socotra, and Yemen (Aden), whereupon she returned to Vladivostok on 3rd July 1979. In all, the carrier's Yak-38s made 253 flights during the cruise in the course of 20 flight shifts; a total of 55 flight hours was logged.

During the passage of the *Minsk* through the South China Sea area flights were performed for the purpose of practising the short rolling take-off in high ambient temperature and humidity. On 8th September 1980 a LII test pilot, Oleg Kononenko, lost his life when performing yet another flight involving a short rolling take-off. The aircraft went beyond the ship's deck and began to lose altitude; for about a minute it continued its flight right above the water, surrounded by a cloud of spray. The pilot had more than enough time to eject to safety, but he struggled to the last moment, attempting to gain altitude and save the machine.

After this accident the Yak-38 was subjected to a series of modifications intended to enhance the reliability of the nozzle rotation system of the lift/cruise engine; corrections were introduced into the techniques of performing the short rolling take-off. It was the 311th OKShAP's CO Yuriy I. Churilov who was the first among service pilots to master this technique.

In early 1981 Yakovlev's OKB-115 prepared for inclusion into a report a comparative table on the operation of two VTOL aircraft: the Harrier (for the period between 1969 and 1980) and the Yak-38 (for the period between 1974 and 1980). It is given on page 99.

As per 1st October 1981, there were 68 single-seat Yak-38s and 17 Yak-38U trainers in service. The number of flights totalled 25,600, including 4,700 flights performed from the decks of aircraft carriers. The total flying time logged by these types was 7,030 hours, of these 1,700 hours were logged in flights from ship deck.

The Yak-38 was demonstrated to the Soviet Minister of Defence Marshal Dmitriy F. Ustinov during Exercise ***Zapad-81*** (West-81) in the summer of 1981. The demonstration was conducted on the carrier SNS *Kiev* in the Baltic Sea, in the vicinity of Kaliningrad. Among those present at the demonstration

Another discarded Yak-38, this time at snowbound Severomorsk-3 AB. This machine obviously changed its tactical code during its career.

were also the Ministers of Defence of the Warsaw Pact nations.

One more secret show of Soviet aviation hardware took place at Chkalovskaya AB near Moscow on 23rd January 1982. The show was conducted in hangars, so as to prevent satellites from spotting the event. The aircraft put on show included the MiG-23, MiG-29, MiG-31 and Su-27 fighters, the MiG-27 and Su-17 fighter-bombers, the Su-24 tactical bomber, the Su-25 attack aircraft, the Mil' Mi-28 and Kamov V-80 (Ka-50) combat helicopters and the Mi-8 transport/assault helicopter. Among the new examples of aviation hardware was a production Yak-38 (f/n 0706) carrying two Kh-23 missiles and a Delta guidance system pod on its pylons.

A production Yak-38 was demonstrated again on 12th December 1982 – this time to a delegation from India, a friendly nation.

In the course of the Yak-38's trials operation from the Type 1143 carriers it came to light that the airflow in the ship's bows above the flight deck was turbulent. This was especially the case in the area of the first and the second take-off pads at the front end of the deck during the short rolling take-off. In the first quarter of 1982 TsAGI conducted investigations of the airflow above the deck, using a 1/100th scale wooden model of the *Minsk*. Devices were developed for the purpose of improving the carrier's aerodynamics. As a result, it was recommended that the ships be fitted with special fences in the bow part of the flight deck and fairings on the sponson supporting the angled flight deck and on the Vympel radar. Initially these devices were installed on SNS *Minsk*. The additional devices imposed limitations on the use of on-board weapons, reducing the field of fire; nevertheless, it was decided to fit them also to the new carrier SNS *Novorossiysk*, which featured a slightly different configuration. Three transverse fences and a wall were mounted on the ship's foredeck, extending up to the front end of the flight deck. They served the purpose of destroying the vortex travelling along the ship's side. Furthermore, a specially shaped fairing or 'lip' was welded to the forward edge of the flight deck; it helped streamline the airflow right ahead of the deck.

In the autumn of 1982 the Soviet Navy took delivery of the third Type 1143 aircraft carrier, SNS *Novorossiysk*. On 17th October 1983 she left Kola Bay in the Barents Sea at the head of a task force. It crossed four oceans and 11 seas, circumnavigating three continents and calling at the ports of Angola (Luanda), Yemen (Aden), the island of Socotra and India (Bombay), and safely arrived in Vladivostok, having covered a distance of 20,000 miles. In the course of the 134-day voyage the Yak-38s and Yak-38Us of the ship's carrier wing performed nearly 600 flights, logging a total of nearly 300 flight hours. This number included the 180 test flights that had been made. It was on this cruise that the pilots mastered the new type of flights – the short rolling take-off. By the end of the voyage 120 take-offs of that kind had been accomplished. The fact that the 311th OKShAP CO Col. Yuriy I. Churilov was awarded the Hero of the Soviet Union title for the successful mastering of new combat materiel says a lot for the results of this voyage.

Comparison of Yak-38 and BAe attrition rates

	Number of aircraft in squadron service	Number of accidents	Total hull losses	Fatalities
Harrier	241	83	57	25
Yak-38	115	16+2 (in 1981)	12+2 (in 1981)	4+1 (in 1981)

Above: Yak-36M f/n 0201 was preserved in grey colours at the Yakovlev OKB museum in Moscow. This machine retained the old air intake design and narrow-track landing gear.


This Yak-38 is a gate guard at the 279th OKShAP's shore base, Severomorsk-3 AB.

The Monino museum is notorious for repainting its aircraft in odd colours. Lately 'Ye Merry Painters' have struck again: Yak-36M '14 Yellow' (c/n 7977864401137, f/n 0205) now poses as '37 Yellow'...

...while Yak-38 '11 Yellow' (f/n 0706?) has become '38 Yellow'. Both sport a hideously non-authentic shade of blue.

In comparison, Yak-38 '46 Yellow' (c/n 7977864503511, f/n 0104), residing in the Ukrainian National Aviation Museum at Kiev-Zhulyany, retains its proper colours.

One of the main factors adversely affecting the Yak-38's flight safety were the difficulties encountered in the conversion training of the flying personnel. The pilots acquired the necessary skills and built up flying experience rather slowly. Another factor of considerable importance affecting flight safety was the specific nature of the VTOL aircraft's airframe which, as distinct from conventional aircraft, was subjected to strong vibrations and high temperatures.

In the midst of the Yak-38's operational service period, young pilots began to display a negative attitude to the aircraft as a whole and to flying it. Flights were performed only in the daytime in visual flight conditions, no effort was made to master piloting in difficult flight modes and circumstances; the number of flight hours logged was small. As a consequence, the pilots received no promotion in their skill rating. At best, they were awarded the 'Pilot 3rd Class' rating, while the 'land-based' pilots of the same age wore the badges of 'Pilot 2nd class'. During their visits to service units representatives of OKB-115 and GNIKI VVS had to listen to numerous complaints from pilots regarding the Yak-38.

In actual fact, the level of flight safety was affected by numerous factors. Pilots committed errors in handling the aircraft as a consequence of insufficient experience and too few flight hours logged, primarily because of long intervals in flying due to weather conditions. No doubt, the difficulties of piloting the aircraft in the vertical and transitional flight modes also played their role. Specialists of the Institute of Space and Aviation Medicine, in particular, held the opinion that flying the Yak-38 during the landing approach and the vertical descent required the utmost of human abilities from the pilot. Merited Test Pilot of the USSR N. I. Korovushkin said once that there was no other aircraft in the world as difficult to handle as the Yak-38.

The aircraft's design could also be faulted in some respects. The cockpit ergonomics left much to be desired and the lighting equipment was absolutely dreadful. The development of the automatic vertical take-off and landing modes was never completed. Surprisingly, one of the factors was the fact that testing of the machine had not been as thorough as needed.

In 1983 the number of Soviet VTOL aircraft in operational service peaked at 106 single-seat Yak-38s and 30 Yak-38U two-seaters. By November 1989 83 Yak-38s and 17 Yak-38Us remained operational in Severomorsk (North Fleet), Vladivostok (Pacific Fleet) and Nikolayev (Black Sea Fleet). A further nine production machines (five single-seat and four trainers) served for test purposes. Taking a look at the operational service period between 1976 and 1988, the overall number of flight hours logged by the Yak-38 and Yak-38U fleet was 24,302 hours; the two types made 71,733 landings in all. The flight time logged in one mission in the course of this period averaged 20.4 minutes. The fleet leader in terms of flight hours was a Yak-38 coded '31 Yellow' (c/n 797786...605647, f/n 0504); in the course of nine and a half years it logged 391 hours and 1,098 cycles. If one takes a longer period, between 1974 and 1988, the overall amount of flight hours logged was 29,425 hours. This period saw 37 flight incidents/accidents: eight fatal crashes, 21 non-fatal accidents resulting in total hull losses and eight incidents, which does testify to the insufficient reliability of the aircraft.

As time went on, the interest for the VTOL aircraft began to wane due to its limited tactical capabilities. The last sortie of a Yak-38 was performed in July 1991. The surviving aircraft were relegated to the reserve, after which they were progressively scrapped.

Chapter 6

The Shattered Dream

The Yak-41

Yak-41 and Yak-41M Experimental Supersonic VTOL Fighters (*izdeliye* 48 and 48M) Yak-41UT Conversion Trainer (*izdeliye* 48U) (project)

The Yak-38 was severely handicapped by two major deficiencies – the short combat radius (no more than 90 km/56 miles) and the small ordnance load. Its capabilities as a fighter were extremely limited – it could only engage subsonic targets, and then only within visual range because it had no radar. Therefore, as early as November 1973 the Yakovlev OKB and its 'customer' (the AVMF) concluded that the time was ripe for a successor to the Yak-38. The new aircraft was to feature a fire control radar and an expanded range of armament – and, first and foremost, it had to be supersonic. Apart from the Dassault Balzac V mentioned in the introduction, no Western equivalent existed (the Hawker P.1154 supersonic VTOL attack aircraft project did not materialise), and the Balzac remained in prototype form, after all. Thus, the Soviet designers had to go their own way again.

The future fighter was designed around an R79V-300 lift/cruise engine (*izdeliye* 79) – an afterburning turbofan developed by AMNTK Soyuz (***A**viamotornyy **n**aoochno-**t**ekhnicheskiy **k**ompleks* – 'Union' Aero Engine Design Scientific & Technical Complex), as the Tumanskiy OKB was known by then. The engine had been developed under the guidance of Chief Designer Oleg A. Favorskiy. As mentioned in Chapter 2, the project started life as the four-engined Yak-36P with one main engine and three lift-jets; later, however, the project was reworked considerably, receiving the new designation Yak-41.

At first, Aleksandr A. Levinskikh was the fighter's project chief; he was assisted by deputy chief designer Viktor N. Pavlov and project engineer G. A. Markov. Little by little the team of enthusiasts at the Yakovlev OKB working on the supersonic VTOL fighter grew. The young designers A. D. Ryazanov, G. Kuznetsov, B. A. Orlov and B. I. Belov came on board; Sergey S. Agapov handled the design issues associated with the power-plant.

On 26th June 1974 the Communist Party Central Committee and the Council of Ministers issued a directive officially kicking off development of the new VTOL fighter and setting the date when the advanced development project was to be submitted for review. Originally the designers envisaged only a single lift/cruise engine rated at 15,000 kgp (33,070 lbst), dispensing with lift engines, and the first full-size mock-up, which was built in parallel with the design work, reflected this layout. Yet, even as mock-up construction progressed, it became clear that the single-engined aircraft would be virtually impossible to balance in VTOL and hover modes. The mock-up review commission, which was unimpressed by what it saw, came to the same conclusion.

Hence OKB-115 General Designer Aleksandr S. Yakovlev took the decision to revert to the Yak-38's powerplant layout with one main engine and two lift engines. At this point, in 1976 the Air Force's specialists were asked to join in the drafting of the SOR to which the aircraft would be designed. The fighter received the service designation Yak-41 and the in-house product code *izdeliye* 48; Yakovlev appointed Andrey I. Matveyev as the Yak-41's new project engineer, replacing Markov.

Another Communist Party Central Committee/Council of Ministers directive on the subject (No. 984-313) appeared on 11th November 1977, tasking the Yakovlev OKB and AMNTK Soyuz with developing the Yak-41 shipboard VTOL fighter and its R79 main engine respectively. The directive stipulated the main performance parameters and required the aircraft to be submitted for joint State acceptance trials in 1982. The appropriate MAP order No. 489 followed on 20th December 1977. On 30th March 1978 the Soviet Navy C-in-C Sergey G. Gorshkov endorsed the SOR for the Yak-41; the Air Force C-in-C Air Marshal Pavel S. Kutakhov followed suit on 5th April.

The search for the optimum layout was quite lengthy. Having considered and rejected a lot of alternatives, the designers chose to fall back on the experience accumulated with the Yak-38. However, the Yak-41 did not copy its predecessor completely – the general arrangement was different because of the new powerplant. The main engine was the R79V-300 turbofan specified by the government directive, with a maximum afterburning thrust of 15,500 kgp (34,170 lbst) in horizontal thrust mode or 14,000 kgp (30,860 lbst) in vertical thrust mode, the reduction in thrust being due to the air bleed for the reaction control system. The engine's specific fuel consumption was unprecedentedly low at 0.66 kg/kgp·hr (lb/lbst·hr).

The main engine breathed through two-dimensional lateral air intakes with raked sidewalls and horizontal airflow control ramps. The large intake trunks and the flat underside of the fuselage generated additional lift.

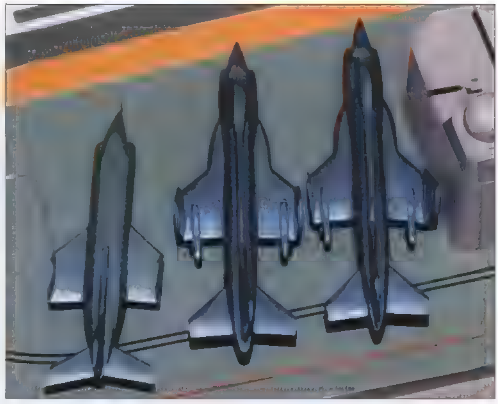
The two lift engines were 4,100-kgp (6,390-lbst) Kolesov (RKBM) RD-41 turbojets. The RD-41 was a single-spool engine with a conical vectoring nozzle that could tilt ±12°30' fore and aft. In one of the PD project versions the lift engines were housed in the fuselage nose (in a bay between the cockpit and the radar set), which resulted in an extremely long nose. However, it turned out that the exhaust gases of the lift engines would be kicked up squarely into the main engine's air intakes; the designers chose to leave well enough alone and placed the lift engines aft of the cockpit, as was the case with the Yak-38; the engines were inclined 10° forward. Incidentally, this project version featured a transverse structural member connecting the tips of the tailbooms for added stiffness and structural strength, but this feature was also rejected in the long run.

The lift/cruise engine's afterburner dictated the use of a single vectoring nozzle, which had to be located close to the aircraft's CG. This led the designers to use an unconventional layout with twin boxy tailbooms flanking the engine; the tailbooms carried twin vertical tails and all-movable slab stabilisers (stabilators). Unlike the Yak-38, the wings of the Yak-41 were shoulder-mounted, not mid-set, and featured scimitar-shaped leading-edge root extensions. The wings and tail surfaces all had a trapezoidal planform; again, the wings could be folded for below-deck stowage.

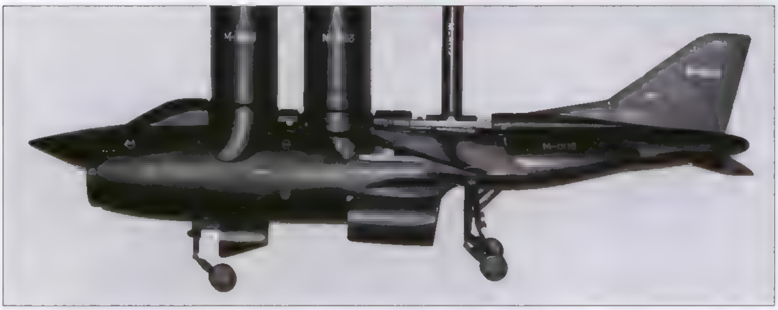
The Yak-41's general arrangement and internal layout were finalised in July 1980 and the OKB embarked on the detail design stage. Probably as an insurance policy in case the new R79V-300 engine should prove

These models show how the two concepts of the Yak-41 evolved. Above: This tadpole-like single-engined aircraft was proposed by Leon M. Shekhter's team.
Right: This three-engined model is very close to the real Yak-41, except for the lateral doors covering the main engine's vectoring nozzle.

Above: A later version of 'Shekhter's Monster' with an air intake centrebody and main gear units retracting aft into wing fairings.
Right: An early three-engined model with a 2-D vectoring nozzle and lift engines placed ahead of the cockpit. The tactical code may hint at the year of development.



Above and right: A model of the Type 1143 aircraft carrier built by NPKB, with models of the single-engined Yak-41 on the deck. They represent a cross between the models on page 102, combining the fuselage of '71 Yellow' with the wings and main gear of '74 Yellow'.
Above right: A model of the Yak-38 was provided for comparison.
Below: A wind tunnel model of the early 'tadpole' rigged for exploring the jet efflux pattern.



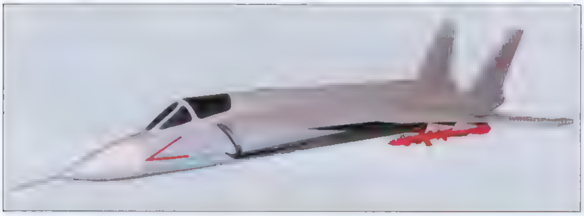
to be a lemon, the designers were working in parallel on the so-called 'analogue' – a version utilising a suitably modified Solov'yov D-30 commercial turbofan as the lift/cruise engine. However, in March 1982 General Designer Aleksandr S. Yakovlev called a halt to this line of development.

When the ADP of the Yak-41 had successfully passed the customer review stage (the mock-up review commission was chaired by Col. Gen. A. N. Tomashevskiy acting on behalf of both the Air Force and the Navy), it was decided to build four development aircraft as part of the test programme. The first example (c/n 01), known as *izdeliye* 48-1, was envisaged as a ground test article for captive tests of the powerplant and the aircraft's systems. The second aircraft (*izdeliye* 48-2, c/n 02) and the third aircraft (*izdeliye* 48-3, c/n 03) were the flying prototypes; at the initial stage of the flight tests the two machines were to be used for exploring the conventional flight mode (that is, for performance testing) and the VTOL mode respectively. Finally, the fourth example was the static test airframe and bore the designator *izdeliye* 48SI (*sta**tich**eskiye ispy**tah**niya* – static tests).

Concurrently with the basic single-seat fighter, the OKB was working on a two-seat trainer variant featuring a longer forward fuselage with tandem cockpits. The latter was designated Yak-41UT (*oo**cheb**no-treni**rov**ochnyy* – for conversion and proficiency training) and bore the in-house code *izdeliye* 48U.

In the early 1980s Viktor N. Pavlov succeeded Aleksandr A. Levinskikh as the Yak-41's project chief. In 1983 Konstantin F. Popovich was appointed deputy chief designer; he, too, subsequently rose to project chief.

Initially the OKB intended to commence flight tests in 1982 in keeping with the Council of Ministers directive; yet a host of technological problems arose, causing the development schedule to slip. In particular, originally AMNTK Soyuz envisaged a two-dimensional vectoring nozzle for the R79V-300; yet



A lot of alternative configurations were tried after the OKB dropped the single-engined concept.

Top: One of the PD projects was remarkably similar to the Yak-38, featuring a single vertical tail and a main engine with twin buried nozzles.

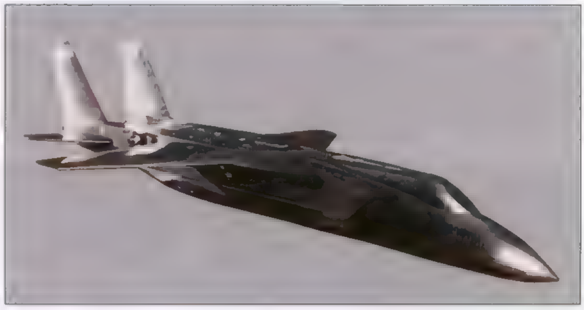
Second from top: A model utilising a blended wing/body, tail-first layout with twin fins and semi-circular air intakes.

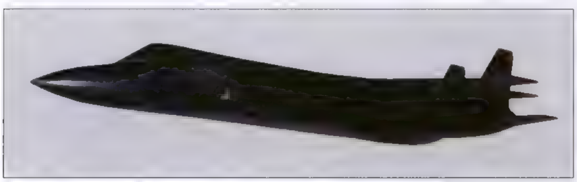
Above: This model (aptly coded '41 Yellow') is very close to the final version, except for the Starfighter-style semi-circular intakes with half-cones.

Top right and above right : Another version using the canard layout, this time built along more conventional lines and featuring two vectoring nozzles.

Right: This model has high-set main engine intakes and a 2-D vectoring nozzle.

developing such a nozzle proved to be too much of a technological challenge and a conventional axisymmetrical nozzle had to be used. Then the engine makers adopted an ingenious solution, dividing the jetpipe into three segments whose joints lay in two intersecting planes located at an angle to the engine axis; thus the centre segment was conical in side elevation. The rear segment carried an adjustable nozzle. For thrust vectoring the centre and rear segments rotated in opposite directions by means of a hydraulic motor and reduction gearboxes linked by shafts with universal joints; in so doing the jetpipe curved smoothly downward so that the axis of the rear segment tilted through 95°. For a short rolling take-off the nozzle tilted through 62°. The nozzle position was selected





Top and top left: '47 Yellow' represents the configuration of the Yak-41 that was eventually finalised, using a conventional (non-BWB) design with raked two-dimensional air intakes and an axisymmetrical vectoring nozzle between two tailbooms. Note the brake parachute container above the engine nozzle.

Centre and above: A wind tunnel model of the Yak-41 in the final configuration. The fixtures allow it to be placed in the tunnel with different angles of attack.

Left and above left: Another wind tunnel model of the Yak-41. This all-black model with large leading-edge root extensions was displayed at the 38th Paris Air Show in 1991 as the 'Yak-141'.

manually by the pilot or automatically by the acceleration module. For the first time in world practice, the afterburner could be used in both horizontal and vertical thrust mode.

Of course, this also represented a technological challenge – the segments rotated in huge roller bearings and the joints needed to be sealed to prevent seepage of hot exhaust gases. Yet this design, which was duly patented, proved so effective that many years later Rolls-Royce used the same principle in its lift/cruise engine nozzle developed for the Lockheed Martin F-35B Lightning II – the V/STOL version of the Joint Strike Fighter.

The R79V-300 had triplex full-authority digital engine control. In cruise mode the FADEC had a hydromechanical back-up.

Another area that required much attention and required lengthy development was the control system. The Yak-41 featured a fly-by-wire (FBW) control system, the stick and rudder pedals having no mechanical link with the control surfaces, and the engines were also integrated into the system (that is, 'power-by-wire'). Since the new vectoring nozzle developed for the R79V-300 necessitated additional bench tests, on 25th November 1983 the VPK passed ruling No. 413 postponing the Yak-41's State acceptance trials until 1985.

Above: A later model of the Type 1143.5 aircraft carrier built by NPKB. In this case 'production' Yak-41 trijets share the flight deck with Sukhoi T-10K (Su-27K) CTOL fighters; the latter are in an early configuration lacking canard foreplanes.

Above left: A large metal model of the Yak-41 used for tests.

Far left: The fuselage of the first Yak-41 (the *izdeliye* 48-1 ground test article) in the assembly jig at MMZ No. 115.

Left: An early cockpit mock-up of the Yak-41 with Yakovlev OKB chief test pilot Andrey A. Sinitsyn sitting in it. The instruments at the top are not part of the flight instrumentation.

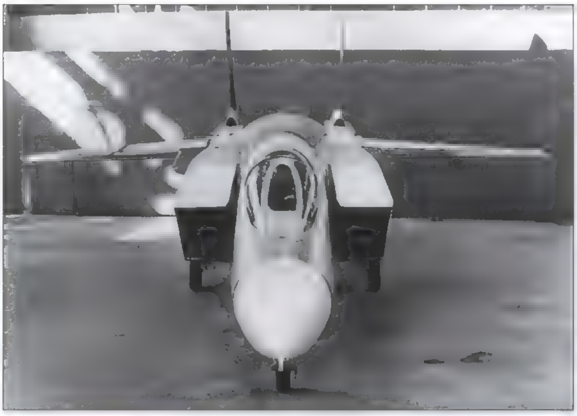
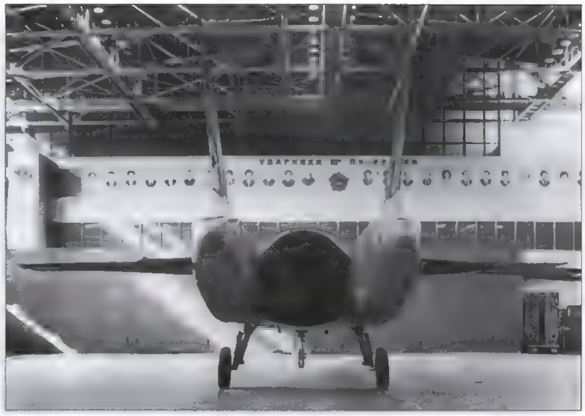
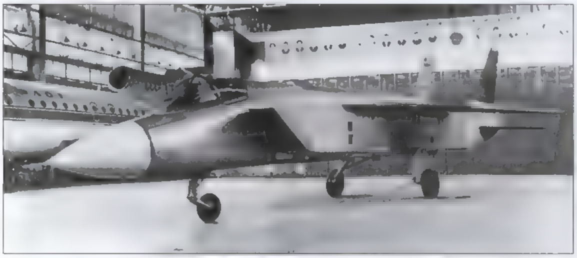
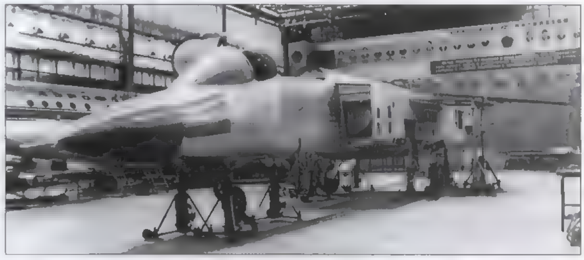
Far left and below left: The first Yak-41 takes shape.

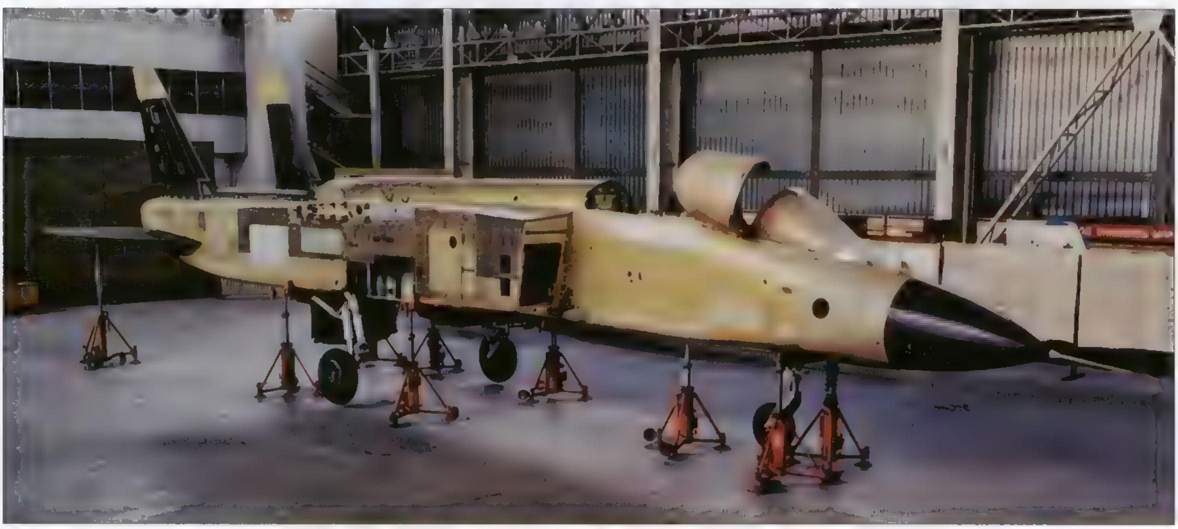
Left and below: Here, Sinitsyn is pictured in a later cockpit mock-up of the Yak-41 featuring cathode-ray tube (CRT) displays and a head-up display.

Right: Two different Yak-41s (apparently the 48-1 and the first prototype, *izdeliye* 48-2) nearing completion at MMZ No. 115. Note the black fins made of carbonfibre reinforced plastic.

The Yak-41's weapons control system was based on the Phazotron S-41 fire control radar which had both air-to-air and air-to-surface capability; this radar was required to enter flight testing on the Yak-41 in the third quarter of 1985. The third prototype of the fighter was to feature an improved S-41D radar (*dora**bot**annyy* – modified) enabling the Yak-41 to launch Kh-35 anti-shipping missiles at a maximum range of 120 km (74.5 miles). Moreover, plans were in hand to begin testing the even more refined S-41M version (*modernizeerovannyy* – upgraded) in 1987 which would allow the fighter to carry Kh-31 and Kh-35 ASMs and other types of air-to-air and air-to-surface missiles.

89.5% of the design documents and manufacturing drawings for the ground test example (*izdeliye* 48-1) had been issued by September 1983; at that point the aircraft itself was 35.2% complete. The project documentation for the first prototype (*izdeliye* 48-2) and the static test airframe was 45% complete. Aptly coded '48 Yellow', the ground test example was finally completed in the first quarter of 1984; V. Sochilin was appointed the aircraft's project engineer. On 19th March Aleksandr S. Yakovlev ordered the machine delivered from the prototype construction facility (MMZ No. 115) to the OKB's flight test facility in Zhukovskiy by 1st May. Yet this order could not be complied with because the aircraft was still engineless: MMZ No. 115 did not take delivery of the first R79V-300 engine (c/n 03) until June 1984. The dry weight of this particular engine less nozzle was 1,515 kg

Top, centre and above: '48 Yellow', the *izdeliye* 48-1, after rollout. Despite being non-flyable, it wore full insignia. Note the lack of the rear reaction control puffers and the large nosewheel.

'48 Yellow' erected on the SSM dynamometric rig, with FOD protection screens on the air intakes. Note the open jet blast gate below the aircraft.

(3,340 lb); the vectoring nozzle weighed another 255 kg (562 lb). Another flight-cleared engine was delivered to the OKB in early July 1984 (instead of January as planned); this example was to undergo flight tests as part of a DLL rig suspended beneath one of LII's Tu-16LL engine testbeds. The tests of this engine began in August.

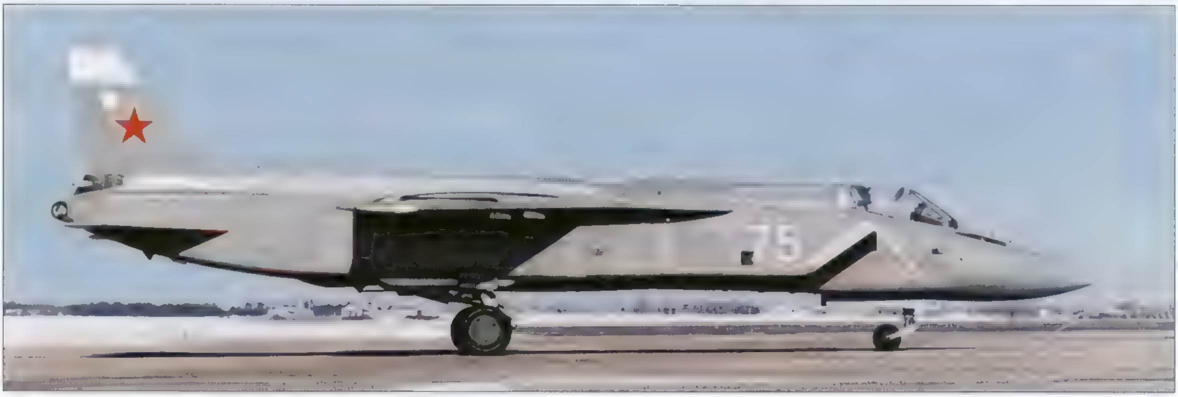
17th August 1984 was a memorable day for OKB-115 – the design bureau's founder and leader Aleksandr S. Yakovlev retired due to advanced age and failing health. Four days later, on 21st August, Minister of Aircraft Industry Ivan S. Silayev signed order No. 760K appointing Aleksandr A. Levinskikh as acting chief of MMZ ***Sko**rost'* (Speed; the official name of OKB-115 until the late 1980s). 'The king is dead, long live the king'? No – Levinskikh never became General Designer and headed the company only briefly, being soon succeeded by Aleksey N. Dondukov.

Apart from the Yakovlev OKB, numerous other enterprises were involved in the Yak-41 programme. The most important of these were AMNTK Soyuz (which supplied the main engine), NPO Phazotron (*na**ooch**no-proiz**vod**stvennoye obyedi**nen**iye* – Scientific & Production Association) which was responsible for the radar, and GosNII AS – the Soviet Union's leading systems and avionics integrator. The engine maker and the radar house were the main culprits behind the repeated slippages of the development schedule because the R79V-300 turbofan and the S-41M radar had their fair share of development problems, which meant they could not be delivered on time. For instance, in 1984 the plan was that the second prototype Yak-41 (*izdeliye* 48-3) fitted with the S-41M radar and an updated weapons control system would

Two more views of the *izdeliye* 48-1 on the dynamometric rig. The underlying surface is protected by AK-90F ceramic tiles. Interestingly, the nosewheel and the lift engine air intake scoop were removed in the course of the tests. Note that the SSM rig is located in a shed protecting it from US surveillance satellites.

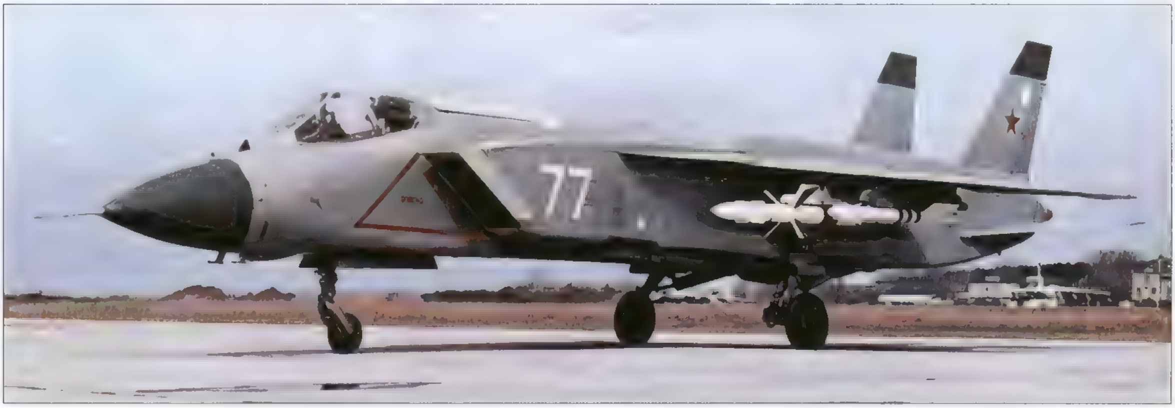
enter manufacturer's flight test in 1986, with the similarly equipped third and fourth prototypes (*izdeliye* 48-4 and 48-5) following suit in 1987. A while later, when it became clear that the radar would not be available on schedule anyway, the test schedule was revised. The first two prototypes of the single-seater (*izdeliye* 48-2 and 48-3) were now due to be ready in 1985, the static test article (*izdeliye* 48SI) following in 1986. The prototype and the static test airframe of the trainer version (*izdeliye* 48UT and *izdeliye* UTSI) would be completed in 1987 and, finally, the first example of the radically modified Yak-41M (*izdeliye* 48M, see below) was to follow in 1988.

As of 1st March 1985, the test schedule required the '48-2' to commence manufac-



Three aspects of '75 White', the first flying prototype (*izdeliye* 48-2). Note the reaction control puffers at the tips of the tailbooms and the small nosewheel.

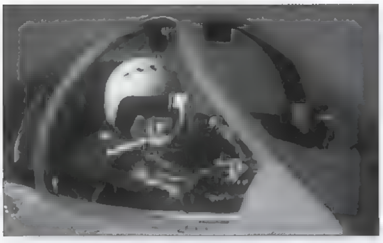
Above: The first flying prototype Yak-41 makes its maiden flight on 9th March 1987, taking off conventionally at Zhukovskiy. The deployed leading-edge and trailing-edge flaps are visible.



Centre: The second flying prototype, '77 White' (*izdeliye* 48-3), poses with dummy R-73 and R-27R AAMs; this is the only available photo of it with weapons. Above: The same machine minus missile launch rails. '77 White' also had a small nosewheel.

turer's flight tests in the fourth quarter of that year – initially minus radar; the S-41M radar would be retrofitted a year later, in the fourth quarter of 1986. This aircraft was to be submitted for joint State acceptance trials with the ability to carry two K-77 radar-homing medium-range AAMs and two K-73 IR-homing short-range AAMs. In addition to these, the '48-3' would be able to carry a single Kh-31A or Kh-35 anti-shipping missile on the centreline, commencing State acceptance trials with this weapons fit in the second quarter of 1987.

The plan also stated that two Yak-41M fighters from a low-rate initial production



Top and above: Andrey A. Sinitsyn, the Yakovlev OKB's chief test pilot, in the cockpit of one of the Yak-41 prototypes.

(LRIP) batch built by the Saratov aircraft factory No. 292 were to enter manufacturer's flight tests in 1987, their joint State acceptance trials being scheduled for the second quarter of 1988. The Saratov aircraft factory was also tasked with manufacturing two Yak-41UT trainer prototypes; the first of these was to enter manufacturer's flight tests in 1988 and be submitted for joint State acceptance trials in the second quarter of 1989.

Meanwhile, the development programme of the Soviet supersonic VTOL fighter reached another milestone. At an early stage of the programme MAP had decided to build an SSM force and momentum measurement rig with a jet exhaust evacuation system on the premises of the LII airfield. The rig served a dual purpose: apart from measuring the forces arising in all three control channels during the operation of the powerplant and the reaction control system, it would be used to verify the measures intended to stop the fighter's lower fuselage skin from being burned up by the hot jet exhaust. Only by running the engines of the *izdeliye* 48-1 ground test article ('48 Yellow') on the SSM installation could the designers ascertain how the efflux of the main and lift engines was distributed beneath the aircraft and develop measures preventing FOD and exhaust gas recirculation. Development of the SSM rig was entrusted to the GhiproNIIaviaprom research institute headed by Ivan I. Shandura.

After lengthy wind tunnel tests of a model of the SSM installation the designers settled for the following arrangement. Yak-41 '48 Yellow' was erected on three supports (under the wings and the forward fuselage) above a steel platform whose surface was covered with special AK-90F heat-resistant tiles. In the platform there was a jet blast deflector trench closed by special sliding gates. The supports were rigged with strain gauges for measuring the forces applied to the aircraft at different engine power settings and during operation of the reaction control puffers. The supports were adjustable, allowing the aircraft to be fixed at various bank angles and angles of attack; this made it possible to assess the powerplant's operation in all critical flight modes.

The aircraft was mounted 4 m (13 ft 1½ in) above the surface of the platform. The latter measured 24 x 24 m (78 ft 8⅞ in x 78 ft 8⅞ in). From above it was protected by a flat roof mounted on poles 12 m (39 ft 4 in) tall; this shed was not so much for protection against the elements – rather, it concealed the installation from US surveillance satellites. The sliding gates above the blast deflector trench were remote-controlled; they were open at the start of the test session. Once the engines had been started and full power selected, the pilot gave the command and the gates were closed, creating a 'solid' surface below the aircraft. The blast deflector trench itself was 1.8 m (5 ft 10⅞ in) deep, 10 m (32 ft 9¾ in) wide and 24 m long. At the end of the trench the lift/cruise engine's exhaust jet was directed 45° up and struck a deflector grille which slowed down the efflux stream and mixed it with the ambient air, reducing the temperature. The exhaust gases exiting the lift/cruise engine nozzle had a temperature of 980-1,050°C (1,796-1,922°F) and a velocity of 950-980 m/sec (3,116-3,215 ft/sec). In comparison, after the efflux passed through the deflector grille the figures were reduced to 250-300°C (482-572°F) and 150-200 m/sec (492-656 ft/sec) respectively.

All of the powerplant's operating parameters were captured by recording equipment located in a small building 20 m (65 ft) away. The aircraft's fuel tanks were empty, the fuel being supplied by a pipeline from a tank located some 30 m (100 ft) away for safety's sake. A special device was provided to ensure pilot evacuation in an emergency in these unusual operating conditions; it jerked the cockpit canopy open by means of a cable running at approximately 30° to the fuselage and forcibly extracted the pilot, lowering him to 1 m (3 ft) above the ground 10-15 m (33-50 ft) from the aircraft.

Another purpose-built installation constructed at the LII airfield as part of the Yak-41's test programme was a vertical take-off and landing pad made up of 1.2 x 1.0 m (3 ft 11¼ in x 3 ft 3⅜ in) cast-iron slabs 60 mm ($2\frac{23}{64}$ in) thick joined along the edges.

The initial stage of the ground tests – the so-called Stage G (for *gorizon**tahl'*** – 'horizontal tests') – took place on the SSM test rig between 26th September and 12th December 1984. It included 12 high-power engine runs with the lift/cruise engine nozzle in the horizontal (cruise flight) position, hence the name of the stage. It was followed by Stage V (*ver**tikahl'***), which lasted from 8th February to 25th August 1985 and involved 39 runs of the powerplant in vertical thrust mode. The third and final stage (from 5th June 1986 to 24th

Landing light blazing, the first flying prototype comes in to land on the aircraft carrier SNS *Baku*.

The second flying prototype performs a hover; again, FOD protection screens are fitted. Note the open main engine nozzle door and the deployed transverse recirculation dams.

April 1987) included 43 engine runs involving a transition from vertical to horizontal thrust or vice versa. All in all, 94 runs of the powerplant were made on '48 Yellow', using the SSM rig.

The ground tests of the powerplant proved to be a time-consuming task. In the course of 1989, *izdeliye* 48-1 made a further 63 engine runs on the SSM rig; 36 of these were officially credited as part of the trials programme. Later, in 1991, the SSM was used to measure the thermal loads applied to various external stores suspended beneath *izdeliye* 48-1 in order to make sure that the weapons would not become overheated and detonate during a vertical take-off, blowing the aircraft to bits.

The second Yak-41 – that is, the first flying prototype (*izdeliye* 48-2) – was completed in December 1985, receiving the tactical code '75 White'. Outwardly it differed from the ground test example in having a smaller nosewheel and reaction control nozzles at the tips of both tailbooms. G. A. Fedotov was appointed project engineer for this aircraft; he was assisted by designer V. G. Kuznetsov (responsible for the equipment), V. V. Volkov (engineer in charge of the flight tests) and mechanic Zheltukhin. Later, Volkov and Zheltukhin were superseded by engineer A. K. Yegorov and mechanic Makarov.

At long last the Yakovlev OKB had succeeded in obtaining an R79V-300 lift/cruise engine delivering the advertised thrust of 15,500 kgp (34,170 lbst). This engine was installed on the first prototype, and on 5th May 1986 the aircraft was trucked to the flight test facility in Zhukovskiy. In June 1986 MMZ No. 115 completed the static test airframe (*izdeliye* 48SI), and static tests got underway on 5th September that year, continuing until 31st March 1987.

However, as it often happens, the customer's appetite started growing. In the mid-1980s the Soviet military changed their requirements: they wanted the Yak-41 to be a true multi-role combat aircraft, not just a shipboard interceptor. Therefore on 20th May 1986 the Communist Party Central Committee and the Council of Ministers let loose with a directive (No. 581-175) stipulating that the Yak-41 should be equipped with new systems expanding its combat envelope. These included the new PrNK-48M navigation/attack suite (*pritsel'no-navigatsi**on**nyy* ***kompleks***) built around the S-41M radar; the missile armament was augmented by a 30-mm (1.18 calibre) Gryazev/Shipunov GSh-301 cannon with 120 rounds. In this guise the fighter was designated Yak-41M (moderneezeerovannyy – upgraded), receiving the in-house designation izdeliye 48M.

Again, the S-41M radar (alias M002) was developed by NPO Phazotron; it was a derivative of the N001 Zhuk (Beetle) radar fitted to the MiG-29M fighter. Not only could it detect and track more targets at a time, enabling the Yak-41M to engage more adversaries – it also permitted the fighter to carry new advanced AAMs and air-to-surface missiles.

As mentioned earlier, the Saratov aircraft factory was tasked with building an LRIP batch of eight aircraft that included both Yak-41M single-seat fighters and Yak-41UT trainers. According to the production plans handed down by MAP, the factory was to complete one Yak-41M flying prototype and one static test article in 1987, two flying single-seaters in 1988, followed by two flying trainer prototypes in 1989 and two more flying Yak-41Ms in 1990.

In September 1986 the Air Force presented an amended SOR for the Yak-41M multi-role combat aircraft to the Yakovlev OKB. A mock-up review commission representing both the Air Force and the Navy was in session at the OKB on 14th-21st July 1987, studying the advanced development project and the full-scale mock-up of the Yak-41M. Meanwhile, the Saratov aircraft factory began tooling up for production of the fighter. According to the factory's calculations, the production cycle of the *izdeliye* 48 from the day the first metal was cut to the rollout of the completed aircraft would take 420 days. Still, the Yak-41M did not commence manufacturer's flight tests in the first quarter of 1988 as planned because AMNTK Soyuz had failed to supply the lift/cruise engine.

In mid-November 1986 the Yakovlev OKB proposed arming the fighter with upgraded K-77M medium-range radar-homing AAMs developed by GMKB Vympel ('Pennant' State Machinery Design Bureau; GMKB = *gosoo**dar**stvennoye ma**shin**ostro**it**el'noye kon**strook**torskoye by**uro***). Meanwhile, it turned out that the Zvezda OKB responsible for the Kh-35 anti-shipping missile *had not been officially ordered to develop an air-launched version* (the Kh-35 started life as a surface-to-surface missile). Hence the integration of this missile on the Yak-41M would have to wait.

In February 1987 TsIAM filed a report giving the go-ahead to fly the Yak-41 powered by the R79V-300 engine in horizontal flight mode. The manufacturer's flight tests could now commence. The Yakovlev OKB's chief

These air-to-air shots of the second prototype show the undernose fairing of the forward reaction control puffer which replaced the rear puffers (one of the latter is replaced by an FDR in a crashworthy housing). Note also the main engine nozzle door actuator and the black heat-insulating compound on the belly.

test pilot Andrey A. Simitsyn, who had accumulated a lot of experience with the Yak-38, was appointed the Yak-41's project test pilot. He started his acquaintance with the new fighter by 'flying' the simulator developed by the OKB. Next, he familiarised himself with the peculiarities of the Yak-41's powerplant on '48 Yellow', which was erected on the SSM test rig.

A long series of taxi runs and short hops/hovers in the first prototype ensued. The OKB had taken great pains to perfect the aircraft's balance and handling in the VTOL and hover modes, using the SSM rig, and the effort paid off – the first hovers at altitudes up to 5 m (16 ft) presented no difficulty. The Yak-41's airframe structure had been designed with crashworthiness in mind – in the event of a sudden power loss the machine could drop onto the runway (or the carrier's deck) from this altitude without sustaining catastrophic damage. On the other hand, the exhaust jets bouncing off the ground affected the aircraft until it was 2 m (6.5 ft) above the runway surface, and the pilot had to exercise great care and concentration at this point.

On 9th March 1987 the Yak-41 made its maiden flight; piloted by Andrey A. Sinitsyn, '75 White' performed a conventional rolling take-off and a conventional landing. (Incidentally, to enable such landings the prototype was equipped with a brake parachute. Much later, when the Yak-41 was demonstrated at the Farnborough International '92 airshow, this feature caused many a raised eyebrow and drew a lot of snide comments; to quote the aviation reviewer Roy Braybrook, *'Sir Sydney Camm* (the designer of the Harrier – *Auth.*) *must be* rotating *in his grave'*. Apparently the commentators did not realise the parachute was intended for emergency landings in conventional mode, should the vectoring nozzle malfunction, making a vertical landing impossible.)

On 12th and 16th March 1987 the first prototype made two more flights in conventional mode for the purpose of checking the handling characteristics and exploring the flight envelope. Next, the R79V-300 engines of Yak-41s '48 Yellow' and '75 White' and of the DLL test rig that had been carried by Tu-16LL '02 Blue' were removed and returned to the manufacturer for a check-up and modifications. In the course of 1989 the first prototype Yak-41 made another six CTOL flights.

On 23rd April 1987 the Yakovlev OKB revised the development work plan for the Yak-41. The first prototype (*izdeliye* 48-2) was to serve for exploring the flight envelope, checking the aircraft's stability and handling, dynamic strength, and the various systems' resistance to kinetic heating and vibration. The second prototype (*izdeliye* 48-3) would be used for continuing these tests (with the exception of performance testing) and verifying new equipment items. It would also make the first flights with external stores and serve for the initial stage of the live weapons tests.

The first Saratov-built initial production aircraft would serve for renewed stability/handling and performance tests of the production version, as well as for further dynamic strength and kinetic heating/vibration tests and for checking the FBW control system. The second LRIP machine was earmarked for comprehensive tests of the avionics and equipment, including the PrNK-48 nav/attack suite, the SIV optoelectronic visibility simula-

tion system (*sistema imitahtsii vidimosti*) to be used in poor weather, the *Ekrahn* (Screen) flight data recording and built-in test equipment/crew alerting system (BITE/CAS), the Almaz-UP (Diamond) audio (speech) warning module, as well as the electric system and the fuel metering system.

The third and fourth Saratov-built examples were to serve for testing the FBW controls and the WCS; they would also take part in live weapons tests. Finally, the fifth LRIP aircraft was intended for carrier compatibility trials.

On 22nd May 1987 MAP issued order No. 230, following up on a VPK ruling that specified the requirements and deadlines for the Yak-41M (*izdeliye* 48M). Another MAP order (No. 459) revising the requirements and the development schedule appeared on 24th August 1987.

Meanwhile, the second prototype Yak-41 (*izdeliye* 48-3) was duly completed at MMZ No. 115 in June 1987, receiving the tactical code '77 White'. V. I. Zotov was appointed engineer in charge of this aircraft, while Zheltukhin was once again the aircraft's mechanic. '77 White' differed from the first prototype in several respects. First of all, the rear reaction control puffers at the tips of the tailbooms were eliminated and a single puffer in a small fairing just aft of the radome was introduced instead. This required changes to the forward and centre fuselage structure through which the air supply duct of the forward puffer passed. More structural changes to the forward fuselage were caused by the need to accommodate the new S-41M radar; a new air cooling system was developed for the radar set. The FDR was relocated from a position atop the main engine to the tip of the port tailboom.

Moreover, the results of the static tests undertaken with the *izdeliye* 48SI revealed a few weak spots and required more structural changes. The tailbooms were beefed up; so were the upper centre fuselage panel above the main engine, fuselage frame No. 24 and the wing attachment lugs. Reinforcement plates were added to the Nos. 4 and 5 longitudinal beams in the wing structure, and the wing skin at the roots was reinforced with metal profiles.

For the purpose of conducting the initial flight tests a few changes were made to the second prototype's systems. The fuel transfer line from the No. 1 fuel tank and the shut-off valve in the No. 3 fuel tank were sealed off, and a switch controlling the fuel transfer pump in the No. 1 tank was installed in the cockpit. These modifications allowed the pilot to control the fuel usage sequence, thereby altering the aircraft's CG position in flight.

Unlike the first prototype, the aircraft had a fully capable inert gas pressurisation system preventing a fire and explosion in the event the fuel tanks were hit. However, since the system was only meant to be used in actual combat, it was deactivated in the first few test flights of '77 White'.

At the initial flight test phase the second prototype featured a KN-31 nosewheel fitted with a 500 x 150 mm (19.68 x 5.9 in) Model 1 tyre and KT-69/4 III mainwheels fitted with 880 x 230 mm (34.64 x 9.05 in) Model 31A tyres.

The following limits were set for the second prototype's maiden flight and initial stage of the manufacturer's flight tests. The maximum all-up weight and the maximum landing weight were not to exceed 17,350 kg (38,250 lb) and 13,950 kg (30,750 lb) respectively. With a 16,000-kg (35,270-lb) take-off weight the unstick speed in CTOL mode was to be 400 km/h (248 mph) and the landing speed with a maximum landing weight was specified as 340 km/h (211 mph). The landing gear struts could withstand 140 flight cycles but the tyres had to be replaced after only ten flights. The weight and speed restrictions were expected to be lifted after the installation of more durable wheels and tyres. The second prototype's maximum speed was initially limited to 870 km/h (540 mph) at sea level and 1,013 km/h (629 mph) at 5,000 m (16,400 ft).

The aircraft was fitted with the R79V-300 lift/cruise engine bearing the construction number 21.

High-speed taxi runs commenced in March 1989; on 2nd April Yak-41 '77 White' made the first flight in CTOL mode, followed on 11th April by the first hover. Manufacturer's flight tests of the second prototype began in earnest in August 1989. On 29th December the aircraft hovered for the first time; four more hovers were made in January 1990. On 13th June 1990 '77 Yellow' performed the first 'full-profile' test flight involving a vertical take-off and a vertical landing. The first take-off in STOL mode (with the lift/cruise engine nozzle partially deflected and the lift engines running) took place three days earlier, on 10th June.

All in all, the second prototype made 75 flights between 1st January and 15th December 1990. The test missions included validation of the FBW control system, vertical take-offs and landings, and short rolling take-

Andrey A. Sinitsyn poses after a successful test flight in the second prototype Yak-41.

Top and above: Yak-41 '75 White' takes off vertically from SNS *Baku* during carrier compatibility trials.

offs. Specifically, there were 21 hovers, two VTOL flights, two flights involving a conventional take-off and a vertical landing, and five take-offs in STOL mode. Additionally, ten missions involved aborted take-offs as the short rolling take-off technique was being validated. Meanwhile, the OKB performed 27 additional engine runs on the ground test article ('48 Yellow') mounted on the SSM test rig.

Once the first prototype had been modified to incorporate the changes introduced on '77 White', Yakovlev CTP Andrey A. Sinitsyn commenced vertical take-offs and landings in this aircraft as well. However, the pilot immediately noticed that the machine behaved rather differently from the second prototype as far as the deceleration characteristics were concerned; in fact, '75 Yellow' was much closer to the Yak-38 in this respect.

As he came in for a vertical landing at the end of a test flight, Sinitsyn missed the landing pad because he could not slow down in time. He was forced to make additional manoeuvres in the hover before '75 White' touched down in the centre of the designated circle on the pad. It took the specialists a long time to establish the cause of the problem. Unlike the Yak-38, whose lift engine nozzles were fixed, the Yak-41 featured vectoring nozzles on the lift engines as well; this feature allowed it to accelerate faster after a vertical take-off by vectoring the thrust aft and kill the forward speed before a vertical landing by reversing the thrust. Well, it turned out that the lift engine nozzles' automatic control unit was acting up – the radio altimeter was giving incorrect altitude readings, and the control unit would not vector the nozzles to provide enough reverse thrust as the aircraft descended. Once the bug had been fixed, both Yak-41 prototypes behaved identically in the VTOL mode.

Sinitsyn noted that the Yak-41's excellent high-lift devices were a vast improvement over the Yak-38 in level flight; the leading-edge flaps and the manoeuvring trailing-edge flaps enhanced the fighter's agility a great deal. The Yak-41 had a high thrust/weight ratio allowing it to accelerate rapidly after transitioning to level flight from a vertical take-off (the acceleration process was fully automated); it could also lose forward speed very rapidly before a vertical landing. The distance required for deceleration from cruising speed to the hover was just over 1 km (0.62 miles), which was 2 to 2.5 times less as compared to the Yak-38. Apart from the aforementioned vectoring of the lift engines' thrust, this rapid deceleration was assisted by the fact that the nozzle of the main engine could be rotated past the vertical (through 95°). The deceleration was especially effective if the pilot increased the angle of attack during the landing approach.

Between 1st January and 24th September 1991 the first prototype Yak-41 made ten flights; the second prototype was operated far more intensively, making 22 flights between 1st January and 22nd May that year. By 30th January 1991 the two aircraft had made 108 flights between them, including seven short take-offs. The tests showed that with a full ordnance load the Yak-41M clearly outperformed the Harrier throughout the altitude envelope; in 'clean' configuration (without external stores) there was no clear-cut winner, each of the aircraft having an advantage in this or that flight mode.

The programme reached a major milestone on 24th September 1991 when both prototypes were flown to Severomorsk-1 AB in order to commence carrier compatibility trials aboard the aircraft carrier SNS *Fleet Admiral Gorshkov*.

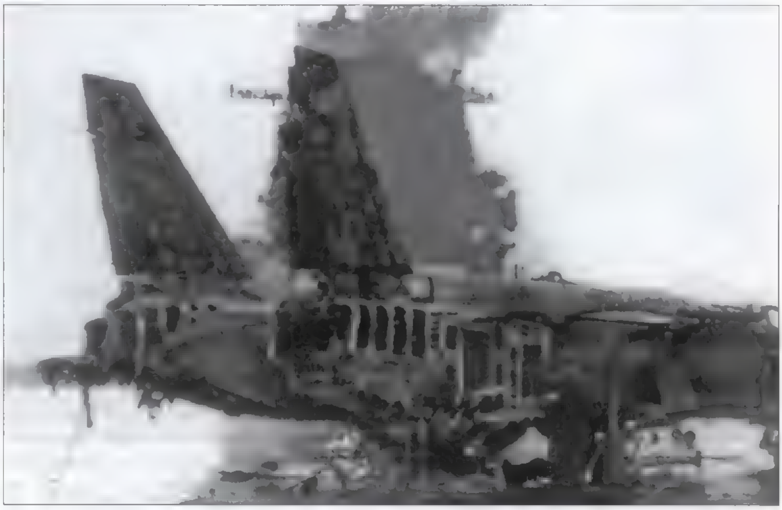
As mentioned earlier, the Yak-41 was viewed as a replacement for the Yak-38s forming part of the carrier wings of the Soviet Navy's operational Type 1143 aircraft carriers; the Yak-38s had reached the limit of their service lives, leaving the carriers with no fixed-wing aircraft. The Yak-41 was also to be deployed aboard future advanced aircraft carriers, including the Type 1143.5 ship SNS *Tbilisi* (later renamed SNS *Fleet Admiral Kuznetsov*). The precursor of the latter ship – the carrier SNS *Baku* – had been commissioned in 1987 (and subsequently renamed SNS *Fleet Admiral Gorshkov*). She was the fourth Type 1143 aircraft carrier, and she incorporated a number of refinements based on the naval pilots' requests and on the results of wind tunnel tests at TsAGI. The *Baku*'s flight deck was extended forward by approximately 10 m (32 ft 9 in) and its front end was carefully faired to minimise the turbulence. For the same purpose the foredeck was 'cleaned up' by removing part of the equipment located there on the other Type 1143 ships and special deflectors were installed; as a result, the airflow over the flight deck when the ship was in motion became less turbulent. Another important change was

that the Type 1143 carriers were widened from 4.6 m to 5.9 m (from 15 ft 1 7/16 in to 19 ft 4 9/32 in), making it much easier to stow the Yak-41 in the hangar.

The flight deck of the SNS *Baku* (SNS *Fleet Admiral Gorshkov*) was 184 m (603 ft 8 in) long and 21 m (68 ft 10 in) wide. This made it possible to operate the fighters from six launch pads whose surface was protected by AK-90F heat-resistant tiles. The launch pads distributed along the flight deck, as well as the two servicing areas at its bow and stern ends, were provided with electric power outlets, centralised refuelling and compressed air charging facilities. A storage and maintenance hangar was located below the flight deck at the stern; it also featured refuelling facilities and all the other required support equipment. Two deck lifts were located on the flight deck centreline, the forward lift measuring 6 x 20 m (19 ft 8 in x 65 ft 7 in) and the rear one measuring 12 x 20 m (39 ft 4 in x 65 ft 7 in); their capacity was 15 and 30 tons (33,070 and 66,140 lb) respectively.

According to calculations, using a short rolling take-off with a run of 70-80 m (230-260 ft) allowed a V/STOL fighter to shoulder an extra 2.5 tons (5,510 lb) of weapons. However, this required the use of special detents that would pop up from the deck ahead of the mainwheels to restrain the fighter until the main engine went to full power. Without them, the fighter would begin to slither along the deck when the engine was spooled up to 80% of full military power. The pop-up detents were developed by the NPKB ship design bureau, B. Ye. Glikin heading the design team. This was a complex and bulky piece of machinery requiring a space of 3 x 2 x 2 m (9 ft 10 in x 6 ft 6¾ in x 6 ft 6¾ in) to fit flush with the deck.

According to the flight test schedule the Yak-41M was to make its first flights from the deck of the aircraft carrier SNS *Fleet Admiral Gorshkov* in late September 1991. On 17th September a mixed test team representing the Yakovlev OKB, NPKB and other participating enterprises and headed by the



Left: A dramatic sequence depicting the crash of the second prototype on SNS *Baku* on 5th October 1991. Top and above: The aftermath of the crash. The extent of the fire damage rendered repairs impossible.

Above: The first flying prototype (ex '75 White') in post-Soviet demonstrator colours as '141 White'.

Yak-41's deputy project chief Konstantin F. Popovich arrived aboard the carrier, which was anchored at the naval base in Severomorsk. Preparations for the arrival of the fighters got underway; the first prototype was to be flown in by the OKB's chief test pilot Andrey A. Sinitsyn, while the second prototype would be piloted by Vladimir Yakimov, another Yakovlev OKB test pilot.

On 26th September Yak-41 '75 Yellow' with Sinitsyn at the controls safely made the first landing on the carrier, thus achieving another important milestone for the aircraft. An hour later, '77 Yellow' put in an appearance; slowing down, the fighter hovered 5-6 m (16-19 ft) above the deck and settled down smoothly in the middle of one of the circles marking the launch positions.

A lengthy period of preparations ensued as the Yak-41s and the ship's equipment were readied for the carrier compatibility trials. The problems pointed out by the pilots were addressed; the ship's support equipment (refuelling facilities, deck tugs and so on) were given a thorough check. Speaking of which, the hangar of SNS Fleet Admiral Gorshkov was big enough to accommodate twelve Yak-41Ms with the wings folded.

30th September 1991 brought another 'first' – at 1610 hrs Moscow time Andrey A. Sinitsyn performed the Yak-41's first carrier take-off, using the pop-up detents; the fighter became airborne after a take-off run of some 60 m (200 ft). After circling once around the ship Sinitsyn made a landing approach and touched down smoothly in vertical mode. All the while the carrier was anchored at the roadstead within sight of the town of Severomorsk.

On 5th October at noon Sinitsyn took off again in the first prototype, again using the short take-off technique; the take-off run was about 70 m. The ensuing landing was uneventful. Next, Yakimov was scheduled to fly the second prototype. The aircraft was heavy, carrying a bigger fuel load and being fitted with dummy missiles into the bargain. Again, the fighter made a short rolling take-off, becoming airborne after a take-off run of 70-80 m. After making a circuit of the ship Yakimov initiated the landing approach, starting the lift engines a little earlier than usual (this had no influence on the subsequent events, though). Slowly approaching the ship's stern, '77 Yellow' hovered above the launch position at an excessively high altitude. The onlookers watched, aghast, as the fighter yawed, positioning itself across the deck, and started losing altitude fast – too fast. When it was 5-6 m above the deck, Yakimov retarded the throttle all the way to idling rpm. The fighter fell onto the deck, collapsing the landing gear, and burst into flames. For several seconds the deck hands stood petrified; then they were galvanised into action and started fighting the blaze. At this moment, on hearing a terse order from the air traffic control shift supervisor, Yakimov ejected and landed overboard, to be picked up minutes later by a standby helicopter. The pilot was unhurt.

Video footage of the spectacular crash showed that the fighter suddenly became unstable, the tail dipped and the aircraft dropped onto the deck from an altitude of 13 m (43 ft). As mentioned earlier, being aware that touching down on the deck of a heaving and rocking ship in the open sea could be a pretty rough experience, the designers had incorporated some strength reserves into the Yak-41's airframe and especially the landing gear. The fighter was designed to survive an impact equivalent to a fall from an altitude of 5 m. This parameter was not chosen by chance – it is at this altitude that a VTOL aircraft is hardest to control due to ground turbulence, the jet efflux bouncing back to hit the aircraft and the suction effect of the spreading efflux, which may cause the hovering aircraft to keel over or simply drop like a stone. Still, a fall from 13 m would be simply asking too much – the Yak-41 was not designed to cope with such loads. The 12-ton (26,450-lb) aircraft impacted the deck with such force that the landing gear rammed into the belly, rupturing the fuel tanks; the escaping fuel was immediately ignited by the jet exhaust.

To top it all, the automatic crew rescue system did not come into play because the aircraft's pitch angle was within the safe limits and the G load at the moment of impact was

The same aircraft taxies out for a demonstration flight at the Farnborough International '92 airshow. The tactical code is now outlined in red.

Above: The first flying prototype hovers at Farnborough in September 1992.

These shots of the Yak-41 from below taken at Farnborough show the glowing combustion chambers of the lift engines as the machine hovers and then transitions to forward flight.

too brief to trigger an ejection. Only on hearing the ATC shift supervisor's yell, 'Eject!', did Yakimov snap out of his momentary state of shock and pull the ejection handles when the aircraft was already lying on the deck. Even though the lift engines' open air intake scoop made it impossible to jettison the canopy, the ejection seat functioned perfectly, smashing through the canopy and taking the pilot to a safe altitude from where he parachuted to safety. A Kamov Ka-27PS SAR helicopter hovering nearby (this was standard operational procedure during the flying sessions) immediately came to the rescue; frogmen jumped into the water from the chopper to extricate the ditched pilot from the parachute lines and harness. In a matter of minutes Yakimov was back on the carrier's flight deck where firefighters were working on the blaze.

This accident demonstrated once again the dependability of the Zvezda K-36LV ejection seat. The seat did an excellent job, rescuing the pilot from a burning aircraft in true 'zero-zero' conditions.

The accident investigation board cited 'certain design deficiencies' as the cause of the crash. The trials resumed with the first prototype, continuing for another fortnight. By 19th October 1991 the two jets had made eight flights on the carrier (including the positioning flights) and the trials programme was 85-90% complete. Yet the crash of '77 White' was a severe blow to the Yak-41 programme and the underlying concept at large. Even though Aleksandr Dondukov, the Yakovlev OKB's new General Designer, commented that 'this kind of thing is not uncommon during the tests of any aircraft, especially a combat aircraft', the accident served as a pretext for curtailing the programme, ending the 20-year development history of mixed-powerplant VTOL jets in the Soviet Union.

The structural and fire damage was so extensive that the second prototype was no longer fit to fly. Yet it was rebuilt as a static exhibit, receiving a new two-tone grey camouflage, the Russian flag on the tails and the spurious tactical code '141 White'. It this guise it was displayed at several airshows.

Meanwhile, the Soviet supersonic VTOL fighter was unveiled to the outside world – albeit under the bogus designation Yak-141. A 1:10th scale mode of the Yak-41 was displayed at the 38th Paris Air Show in June 1991 and video footage of the tests of the real thing was demonstrated. After this the fighter received the NATO reporting name Freestyle.

'The real McCoy' was demonstrated publicly for the first time at the Farnborough International '92 airshow on 6th-13th September 1992 – again as the Yak-141. Before the show, Vladimir Yakimov made a series of training flights at Zhukovskiy in the sole remaining flyable example, '75 White', on 3rd-30th August. Confusingly, immediately before the show the first prototype was repainted in the same two-

Above: The second prototype was rebuilt as a static exhibit after the crash, gaining a similar colour scheme and the same code '141 White'. Here it is seen at Moscow-Khodynka.

The other '141 White' (the flyable one) languishes at the Yakovlev OKB's flight test facility in Zhukovskiy in company with a Yak-42A demonstrator (RA-42423).

World records established by the Yak-41

Class H (Jet-powered vertical take-off and landing aircraft)
Group III (turbojet aircraft)

No. of flight	Date	Description of record	Value
1	11.04.91	Climb time to 12,000 m (39,370 ft), no load	116.15 sec
2	11.04.91	Climb time to 12,000 m (39,370 ft) with a 1-ton (2,205-lb) payload	116.50 sec
3	12.04.91	Climb time to 3,000 m (9,840 ft) with a 1-ton payload	62.41 sec
4	12.04.91	Climb time to 6,000 m (19,685 ft) with a 1-ton payload	74.37 sec
5	12.04.91	Climb time to 9,000 m (29,530 ft) with a 1-ton payload	89.09 sec
6	24.04.91	Payload lifted to 2 km (6,560 ft)	2,507 kg (5,527 lb)
7	25.04.91	Flight altitude with a 1-ton payload	13,115 m (43,030 ft)
8	25.04.91	Flight altitude with a 2-ton (4,410-lb) payload	13,115 m
9	25.04.91	Climb time to 3,000 m with a 2-ton payload	68.82 sec
10	25.04.91	Climb time to 6,000 m with a 2-ton payload	88.88 sec
11	25.04.91	Climb time to 9,000 m with a 2-ton payload	110.10 sec
12	25.04.91	Climb time to 12,000 m with a 2-ton payload	130.64 sec

tone grey camouflage and received the same code '141 White' as the non-flyable second prototype. In this guise *izdeliye* 48-2 arrived at Farnborough aboard an Antonov An-124 Ruslan heavy transport together with a Yak-38M (aptly coded '38 Yellow') which was also owned by the Yakovlev OKB.

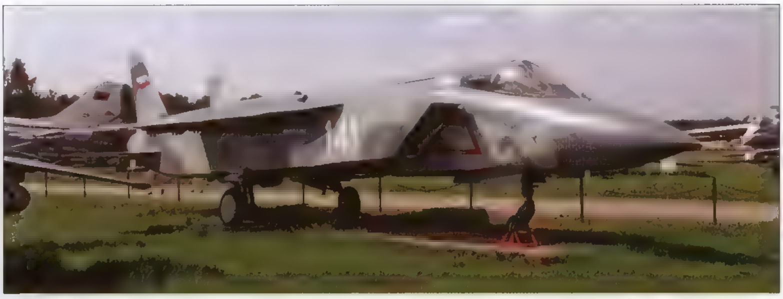
Predictably, the Yak-41 was a show-stealer – especially because it figured in the flying display, too. Yakimov made his first demo flight on 10th September, the fourth day of the show. The western aviation experts voiced differing opinions of the Freestyle. According to *Aviation Week & Space Technology*, 'the Yak-141 was as thrilling as the Yak-38 was uninteresting'. The Yak-41 gave a spirited flying display: what looked at first like a conventional take-off turned into a vertical climb at an 'astonishing' rate as soon as the nosewheel was off the ground. Transitioning to forward thrust, the fighter did a loop immediately and made a circuit of the field. Passing above the runway, the Yak-41 made a series of barrel rolls and vanished from view for a whole minute; then it came back, ignited the lift engines and began slowing down, going to vertical thrust mode. After hovering in front of the crowd at 150 m (490 ft) the aircraft smoothly transitioned to forward flight and made a break to land, touching down in conventional mode.

In contrast, all the Yak-38 did was make a conventional take-off followed by 'very flat and slow turns, leaving a heavy smoke trail'; then, after a brief hover, it performed a short rolling landing.

Some western experts assessed the Yak-41 as being 15 to 20 years ahead of equivalent western technology. Others, however, claimed that the Russian aircraft had not shown its potential to the full. Due to flight safety concerns the aircraft performed at a considerable distance from the crowd line, and many of the onlookers believed that the Russian jet featured nothing that hadn't been seen on the Harrier. Possibly it was the limited time available for practising the flying display and Yakimov's unfamiliarity with Farnborough airfield that prevented him from giving a more spectacular display.

Both Yak-41s marked '141 White' were on display at the MAKS-93 airshow in Moscow – the only Moscow airshow that took place at three different venues at once. The 'live' example (*izdeliye* 48-2) was displayed at the main venue – the LII airfield in Zhukovskiy (unfortunately remaining in the static park), while the 'dead' one (*izdeliye* 48-3) was at Moscow's Central airfield named after Mikhail V. Frunze (Moscow-Khodynka).

On 11th-25th April 1991 Yakovlev OKB chief test pilot Andrey A. Sinitsyn established a series of 12 world records in Yak-41 '75 White', showing that the fighter had no equal



Above and right: Later, *izdeliye* 48-3 was moved to the Central Russian Air Force Museum in Monino and crudely repainted.

among VTOL aircraft. This is when the bogus designation Yak-141 came into being – it was stated in the official papers submitted to the FAI (*Fédération Aéronautique Internationale*) for the purpose of registering the records. This was common practice in the USSR.

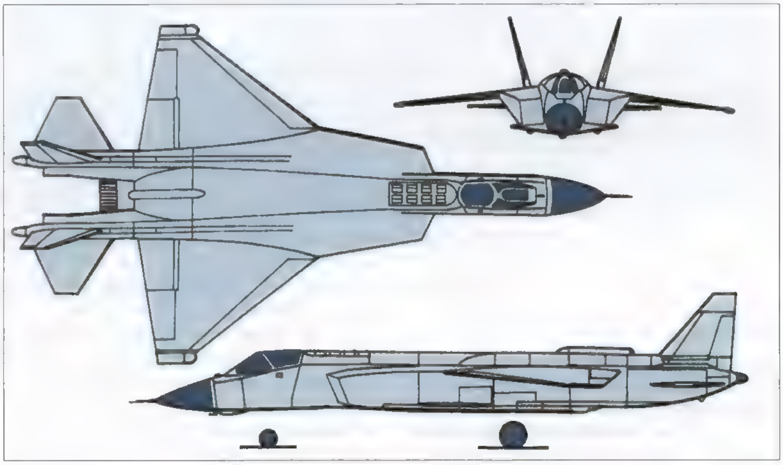
Sinitsyn's record-breaking flights followed a set pattern. Lifting off vertically, the aircraft rose 20 m (65 ft) off the ground and accelerated to 1,000 km/h (621 mph), travelling at 100-200 m (330-660 ft). Then the pilot pulled up into a near-vertical climb and the Yak-41 went up like a rocket, reaching the required altitude with a 270-m/sec (5,310-ft/min) rate of climb.

Of the twelve flights made, four were 'for the record'. The reason for this low number is that the ciné theodolites use by the observers on the ground could not track the aircraft – no one had expected it to climb so fast. Two of the required four theodolites captured the moment of lift-off; the other two located 20-30 km (12.4-18.6 miles) away were supposed to start tracking the aircraft once it climbed through 1,000 m (3,280 ft). However, the rate of climb was so high that the theodolites could not get a lock-on. To facilitate visual tracking a smoke tracer was fitted to the aircraft. Little good did it do – the aircraft climbed so fast that only the flame of the burning tracer was discernible on the developed film.

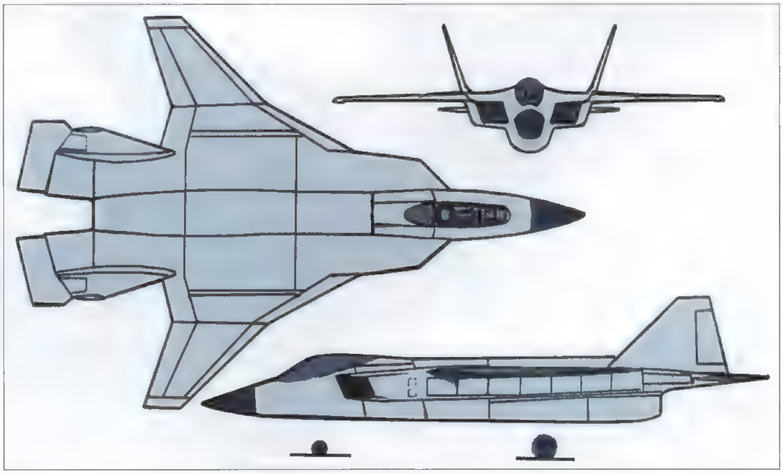
All time-to-height records had to be established at ambient temperatures not exceeding +15°C (59°F), as higher temperatures would cause a reduction in engine thrust. The training flights met this criterion; however, when it came to the actual record attempts, the ambient temperatures had risen, worsening the end result by up to ten seconds. (This showed that there was room for improvement and new records could be set, given the proper conditions.) The Harrier had set a number of records, too, but it had been flown in 'clean' condition; at altitudes up to 3,000 m (9,840 ft) it showed a higher rate of climb than the Yak-41. With external stores, however, the Soviet jet enjoyed complete ascendancy over the Harrier.

On 22nd-27th August 1995 the second prototype Yak-41 was again displayed at that year's MAKS airshow in Zhukovskiy. Thus, Russian aviation fans were denied the chance to see the Yak-41 fly. Later, *izdeliye* 48-3 was dismantled and sat outside the Yakovlev OKB museum in Moscow for a long time.

The manufacturer's flight tests had largely corroborated the Yak-41's estimated performance figures, and it seemed that the fighter had every chance to enter production and service. However, the collapse of the Soviet Union and the ensuing chaos and defence spending cutbacks caused the programme to be shelved. True, the Yakovlev OKB believed that the Yak-41 had furnished a



Above: This three-view shows the early project configuration of the radically redesigned Yak-41M. The aircraft has been misidentified by many sources as the Yak-43, which is actually different.



The final project version of the Yak-41M was even more radically redesigned, featuring a blended wing/body layout; there was not much left of the original aircraft.

Three views of a desktop model depicting the early version of the Yak-41M with the larger LERXes, redesigned air intakes, strongly tapered wings and stabilators, and splayed vertical tails.

lot of valuable data on the behaviour of VTOL aircraft in extreme and abnormal flight modes. Yet the Russian military were understandably reserved in their view of the Yak-41, being undoubtedly put off by all the negative experience with the Yak-38. The Russian MoD concluded that the VTOL aircraft concept needed revision; any future VTOL aircraft to enter service should be different. The supersonic Yak-41 was a highly complex design with many attendant weight penalties; it was also quite demanding as regards operating conditions. Moreover, albeit designed as a shipboard interceptor, the Yak-41 was still outperformed by conventional interceptors; the other missions it was designed to fulfil did not require supersonic performance.

By the end of 1991 the Russian MoD had pulled the plug on the programme, cutting off the funding and concentrating instead on CTOL shipboard fighters. India and China, which were viewed as potential customers for the Yak-41, could not afford to order it either. The Yak Corporation explored the possibilities of cooperation with western aerospace companies that might endeavour to create a next-generation VTOL combat aircraft; however, for various reasons there were no takers.

A wind tunnel model of a projected advanced VTOL aircraft utilising the canard layout. Once again, the aircraft has a mixed powerplant with two lift engines and a single lift/cruise engine

Yak-43 STOL Fighter (*izdeliye* 201) (project)

Back in 1980 the Yakovlev OKB started work on a shore-based derivative of the Yak-41 designated Yak-43 (*izdeliye* 201). This was to be a STOL aircraft with a take-off run of about 120 m (390 ft). It was to feature a blended wing/body layout with a larger wing area; this would provide more internal space for fuel (and hence longer range) and reduce the aircraft's radar signature, making it 'stealthy'.

The Yak-43 was to be powered by a 25,000-kgp (55,115-lbst) Kuznetsov NK-32 afterburning turbofan with a vectoring nozzle.

Next-generation VTOL Aircraft (project)

Despite the Yak-41's financial troubles, the Yakovlev OKB continued its efforts to produce a more capable and 'stealthy' derivative. The new aircraft was to be powered by an uprated lift/cruise engine delivering 17,500 kgp (47,400 lbst); it was to have an all-up weight of 21,500 kg (47,400 lb), including 6,000 kg (13,230 lb) of fuel, and carry up to 4,200 kg (9,260 lb) of ordnance. The maximum range with 1,000 kg (2,205 lb) of ordnance in STOL mode was to be 2,400 km (1,490 miles), decreasing to 900 km (559 miles) with 2,000 kg (4,410 lb) of ordnance. The designers strove to increase the aircraft's combat potential by integrating new weapons and advanced avionics.

Chapter 7

The Yak-41 in Detail

Type: Single-seat supersonic shipboard V/STOL fighter intended for air defence of carrier groups (both close-in dogfighting and beyond visual range (BVR) air combat), for gaining and maintaining air superiority, and for delivering strikes against ground targets and surface ships.

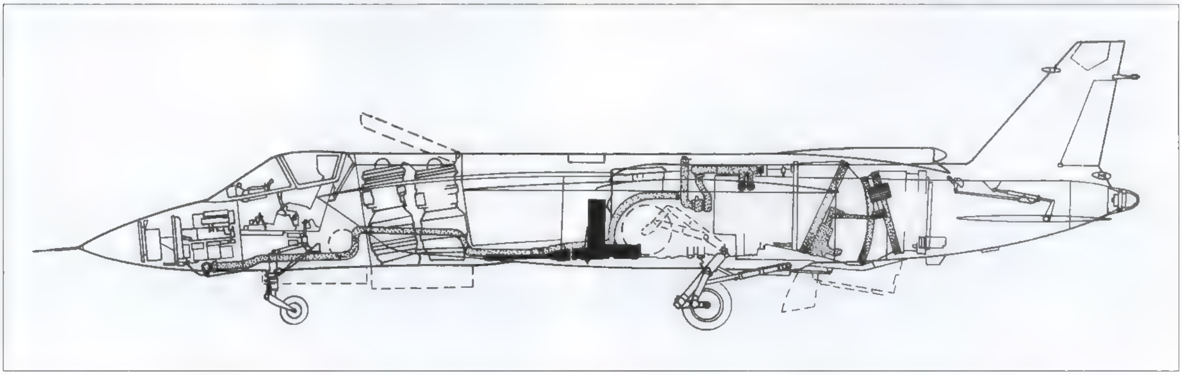
The airframe is of mixed construction, with flush riveting throughout. It is predominantly made of Al-Li alloys. Extensive use is made of composite materials which account for 26% of the structural weight; in particular, carbon-fibre-reinforced plastic is used for the tail surfaces, wing leading edge and trailing-edge flaps, and leading-edge root extensions. High-strength steel and heat-resistant titanium alloys are also used for certain components.

Above: The radome and cockpit canopy of the Yak-41.

Fuselage. The fuselage is a frame-and-stringer semi-monocoque area-ruled structure of basically rectangular cross-section. Structurally the fuselage is divided into three sections: forward, centre and rear. The *forward fuselage* begins with an ogival glassfibre radome tipped with a pitot whose axis is inclined downward. It houses two avionics/equipment bays, the pressurised cockpit, the nosewheel well located below the cockpit and the lift engine bay located aft of it. The cockpit is enclosed by a canopy with a fixed windshield and a section opening manually to starboard. The windshield features an optically flat triplex birdproof windscreen and two curved triangular sidelights made of Plexiglas; the hinged portion has a one-piece blown Plexiglas transparency. As in the case of the Yak-38, the lift engine bay with firewalls fore and aft is closed by an aft-hinged intake door with eight spring-loaded suction relief doors at the top and clamshell exhaust doors at the bottom.

The *centre fuselage* accommodates the lift/cruise engine, its air intake trunks, integral fuel tanks, mainwheel wells and cannon bay. The two-dimensional air intakes have a sharp leading edge which is sharply raked in side view. The flat inner faces of the intakes stand proud from the forward fuselage sides, acting as boundary layer splitter plates; V-shaped fairings spilling the boundary layer connect the intake trunks to the fuselage. The inlet ducts merge at the engine compressor face.

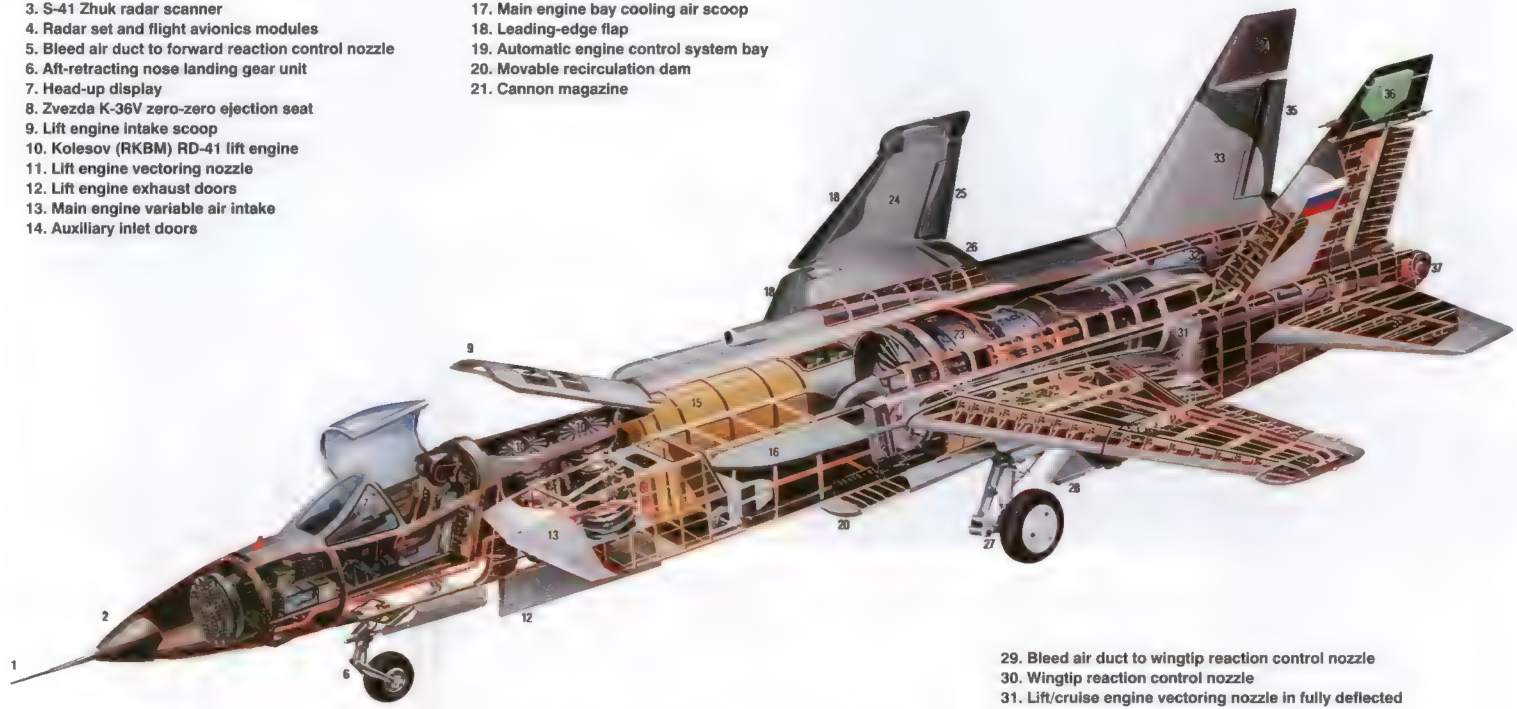
Horizontal strakes of reversed-delta planform are mounted low on the centre fuselage sides; their front portions are integral with the main gear doors. Retractable transverse recirculation dams are located ahead of the mainwheel wells. The rear portion of the centre fuselage bottom is formed by a hydraulically actuated 'snap-action' door for the lift/cruise engine nozzle. This door is flush with the fuselage underside in cruise mode, folding as the nozzle is deflected. (See also Powerplant.)



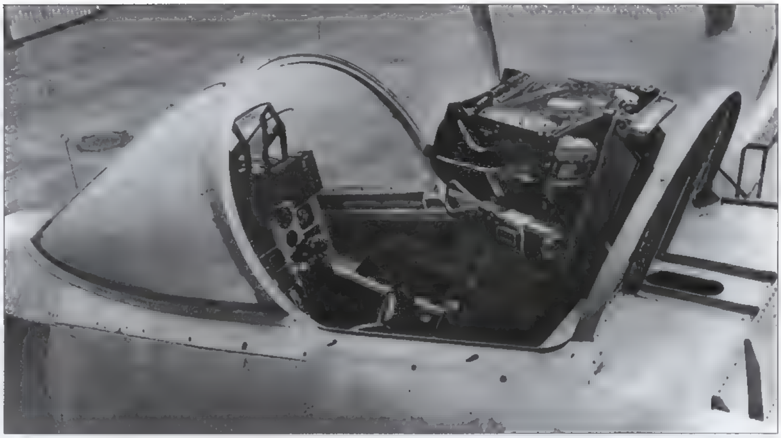
A drawing illustrating the internal layout of the second prototype Yak-41 (note the reaction control puffer under the nose and its supply air duct).

Yak-41 shipboard V/STOL fighter- Cutaway drawing key

1. Main pitot
2. Radome
3. S-41 Zhuk radar scanner
4. Radar set and flight avionics modules
5. Bleed air duct to forward reaction control nozzle
6. Aft-retracting nose landing gear unit
7. Head-up display
8. Zvezda K-36V zero-zero ejection seat
9. Lift engine intake scoop
10. Kolesov (RKBM) RD-41 lift engine
11. Lift engine vectoring nozzle
12. Lift engine exhaust doors
13. Main engine variable air intake
14. Auxiliary inlet doors
15. Forward fuel tank
16. Leading-edge root extension
17. Main engine bay cooling air scoop
18. Leading-edge flap
19. Automatic engine control system bay
20. Movable recirculation dam
21. Cannon magazine



22. 30-mm Gryazev/Shipunov GSh-301 cannon
23. Tumanskiy R79-300 main (lift/cruise) engine
24. Folding outer wing panel
25. Aileron
26. Trailing-edge flap
27. Forward-retracting main landing gear unit
28. External stores pylons
29. Bleed air duct to wingtip reaction control nozzle
30. Wingtip reaction control nozzle
31. Lift/cruise engine vectoring nozzle in fully deflected (vertical thrust) mode
32. Flight data recorder in recoverable buoyant housing
33. Fin
34. Dielectric fin cap
35. Rudder
36. ECM aerial
37. Rear reaction control nozzle
38. Stabilator



Above: The cockpit of a partially completed Yak-41 prototype, showing the ejection seat, instrument panel and HUD.

Two views of the cockpit canopy opening manually to starboard.

The *rear fuselage* is formed by two narrow rectangular-section booms carrying the tail surfaces. It houses aircraft systems, fuel tanks and the rear reaction control nozzles (on the first prototype). The inboard faces of the booms are provided with heat shields tapering off gradually towards the rear.

Wings: Cantilever shoulder-mounted swept-back wings with a kinked trailing edge and large scimitar-shaped LERXes; leading-edge sweep 30°, anhedral 4°. The wings are built in four sections with a power folding feature, the outer wing panels folding upwards for shipboard stowage.

The wings are provided with extensive high-lift devices; these comprise two-section full-span LE flaps and TE flaps on the inboard wing sections. The trailing edge of the folding outer wing sections is occupied by ailerons. The inner wings incorporate four external stores hardpoints. The wingtips incorporate reaction control puffers and ECM/ESM antennas.

Tail unit: The tail surfaces are mounted on two cantilever booms extending aft of the lift/cruise engine. The *vertical tail* comprises twin fins of trapezoidal planform with inset rudders; the fins are almost unswept and slightly canted outwards. The glassfibre fin caps enclose communications and navigation antennas.

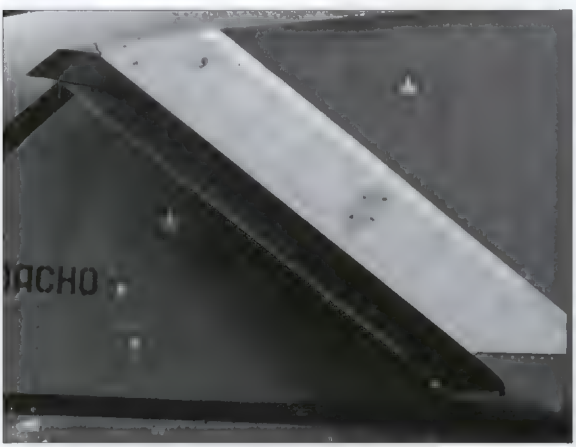
The *horizontal tail* consists of slab stabilisers (stabilators) with a span of 5.9 m (19 ft 4$^{9}/_{32}$ in) mounted below the wing level on the outboard sides of the booms. The stabilators have anti-flutter weights at the roots. Shallow vertical strakes extend forward from the fin roots almost as far as the wing leading edge.

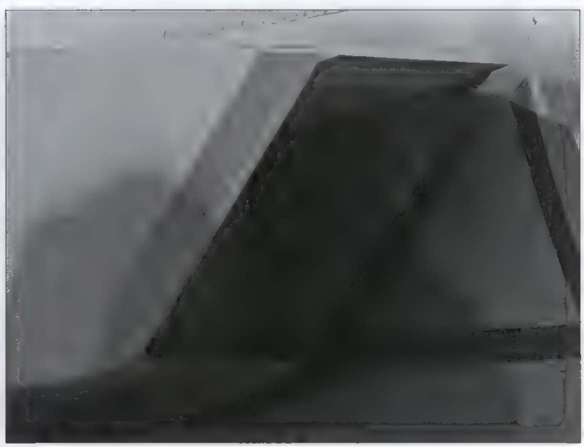
Landing gear: Hydraulically retractable tricycle type, with single wheel on each unit. The semi-levered suspension nose unit retracts aft; the levered suspension main units retract forward, the wheels stowing vertically beside the air intake ducts.

The nosewheel well is closed by two clamshell doors which remain open when the gear is down. Each mainwheel well is closed by a large forward door (opening only when the gear is in transit), a downward-hinged rear door segment and a curved door enclosing the aft-mounted actuating ram. For rolling landings the Yak-41M is equipped with a brake stowed in a fairing above the lift/cruise engine nozzle.

Powerplant: One Kobchenko (AMNTK Soyuz) R79V-300 lift/cruise engine with a maximum afterburning thrust of 15,500 kgp (34,170 lbst) in horizontal thrust mode or 14,000 kgp (30,860 lbst) in vertical thrust mode and 10,980 kgp (24,210 lbst) in cruise mode, plus two 4,100-kgp (6,390-lbst) Kolesov (RKBM) RD-41 lift engines. (Note: Some sources give the dry thrust of the R79V-300 as 9,000 kgp (19,845 lbst) and the thrust of the RD-41 as 4,260 kgp (9,350 lbst).)

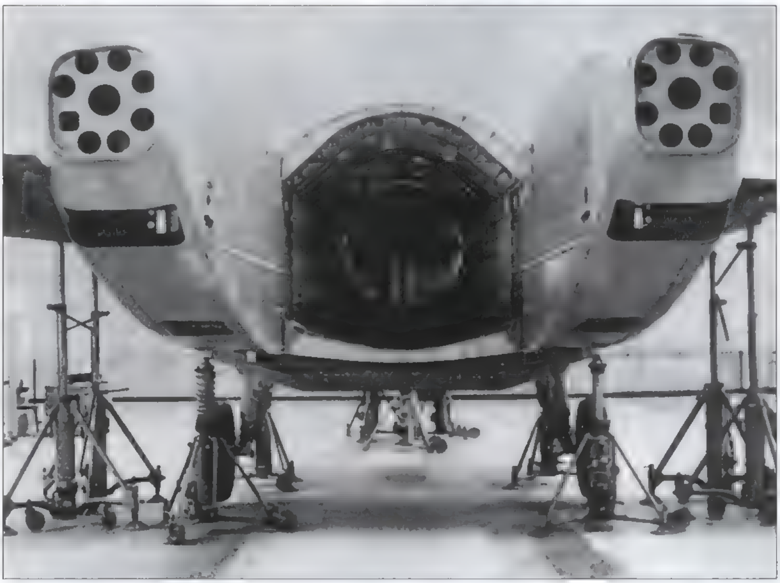
The R79V-300 is a two-spool axial-flow afterburning turbofan. The engine has a mod-



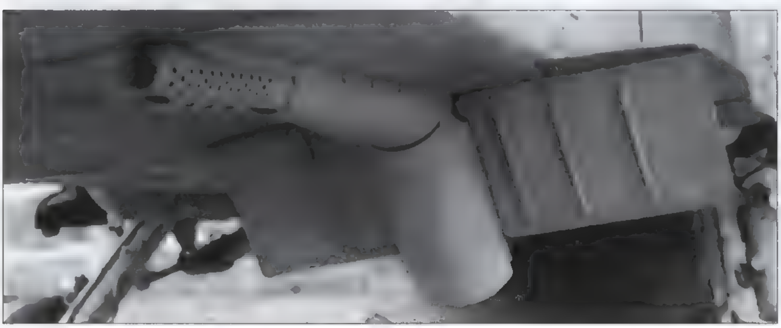


The port and starboard air intakes of the main engine. The inboard faces act as boundary layer splitters.

Above: The 'hot end' of the Yak-41, showing the tapered fairings with heat shields on the insides of the tailbooms. The engine and the ventral nozzle door have been removed. Note the FDR on the port tailboom.



Above: Rear view of an incomplete Yak-41 airframe, showing the main engine bay, the 'snap-action' nozzle door and the hatches on the underside of the tailbooms for access to the tailplane actuators.



The port horizontal strake and transverse recirculation dam (with stiffeners) in extended position. Note how the dam curves around the cannon housing. The cannon features a muzzle brake.

ular design featuring a simple inlet with a parabolic spinner and no inlet guide vanes, a five-stage LP compressor with a mass flow of 120 kg/sec (265 lb/sec), a six-stage HP compressor, a two-zone annular combustion chamber, single-stage HP and LP turbines with air-cooled blades, an afterburner and a vectoring axisymmetrical variable nozzle. The latter deflects downward to a maximum angle of 95° for VTOL/hover or 62° for short rolling take-offs. Thrust vectoring is achieved by means of a hydraulic motor which rotates two conical sections of the jetpipe in opposite directions by means of gearboxes and shafts with universal joints. The service life of the nozzle vectoring mechanism permits at least 1,500 cycles of vectoring.

The LP and HP spools rotate in opposite directions. Bleed valves are provided at the sixth and seventh compressor stages (the first two HP compressor stages) to cater for the reaction control system, lift engine starting and cockpit pressurisation. The turbine stator vanes are air-cooled. The accessory gearbox is located ventrally at the front of the engine casing.

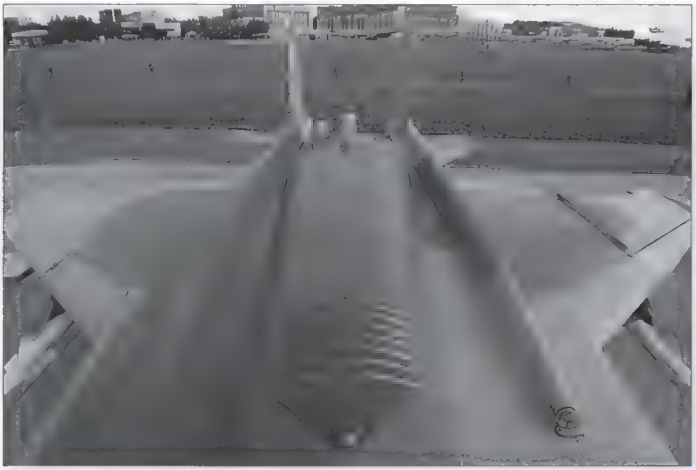
The R79V-300 features triply-redundant full-authority digital engine control (FADEC).

Bypass ratio 0.8; engine pressure ratio (EPR) 22, mass flow at take-off power 180 kg/sec (396 lb/sec), turbine temperature 1,620°K. SFC at take-off power 1.6 kg/kgp·hr; cruise SFC 0.66 kg/kgp·hr. Dry weight 2,750 kg (6,060 lb); length overall 5,229 mm (17 ft $1\frac{55}{64}$ in), maximum diameter 1,716 mm (5 ft $7\frac{9}{16}$ in), inlet diameter 1,100 mm (3 ft $7\frac{19}{64}$ in).

The engine breathes through two supersonic two-dimensional air intakes featuring horizontal flow control ramps and dorsal auxiliary blow-in doors (one on each side). The inlet ducts merge at the compressor face, changing to a circular cross-section.

The RD-41 is an axial-flow non-afterburning turbojet having an air intake assembly with a fixed spinner and multiple radial struts, a seven-stage compressor with variable first-stage stator vanes, an annular combustion chamber, a single-stage turbine and a fixed-area convergent subsonic nozzle. The spool rotates in two bearings; the forward support incorporates a vibration damper. The compressor makes use of titanium alloys and composites; the combustion chamber is made of titanium alloy, while the turbine has a titanium disc and nickel blades.

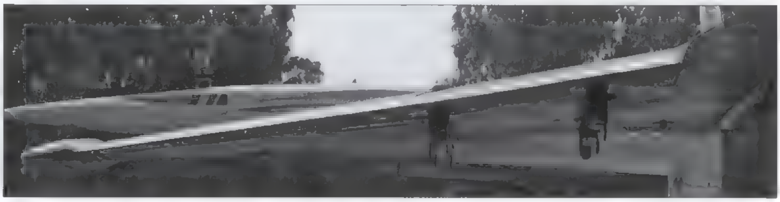
Since the RD-41 is intended exclusively for use with the R79V-300 (not for separate installation), it has no fuel pump of its own – the lift engines' fuel feed system is integrated with that of the lift/cruise engine. The automatic circulation-type lubrication system has no oil pump, with a separate supply of oil for the spool's upper and lower bearings. Starting is by bleed air from the lift/cruise engine



Above: The fuselage/wing upper surface; note the wing folding hinges. Right: The tail unit of the first prototype; the stabilators have anti-flutter weights.

impinging on the turbine (on the ground) or by windmilling. The RD-41 likewise features triply-redundant FADEC; the operation of the fuel shut-off valves and the starting air valves proceeds automatically when the pilot pushed the 'Start lift engines' button.

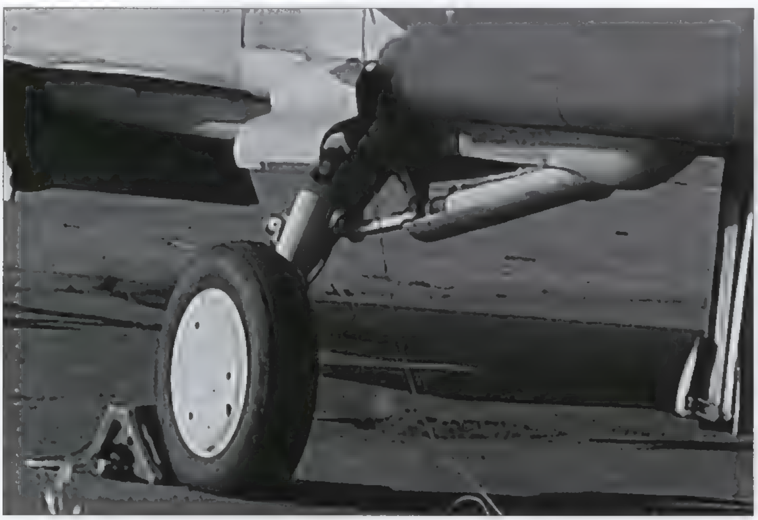
Maximum turbine speed 12,500 rpm; EPR 6.28, mass flow at take-off power 53.5 kg/sec (117.9 lb/sec), turbine temperature 1,480°K. SFC at take-off power 1.4 kg/kgp·hr. Dry weight 290 kg (640 lb), length overall 1,594 mm (5 ft 2¾ in), inlet diameter 635 mm (2 ft 1 in).

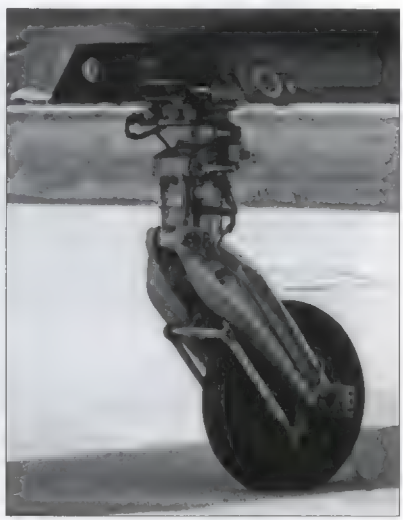


Above: The starboard wing, showing the leading-edge flap, the LERX and the two weapons pylons.

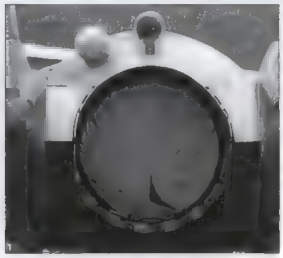
The lift engines are located in tandem behind the cockpit, breathing through a dorsal intake door and exhausting via clamshell doors which close the air intakes and nozzles in horizontal flight. The engines are inclined 10° forward from the vertical; their nozzles can be vectored within ±12°30', resulting in an effective angle of 24°30' rearward for additional forward thrust or 2°30' forward for some thrust braking effec); the nozzle cross-section was variable. In VTOL mode the nozzles of the lift engines are vectored towards each other to form a common jet efflux, while during a short rolling take-off both nozzles are vectored fully aft to create a horizontal thrust component.

The main engine's maximum 95° angle of thrust vectoring is used during vertical take-off and landing. With this nozzle position, the thrust can reach 80% of the engine's rating in horizontal thrust mode. Afterburning can be used in the VTOL mode; this hampers the use of the aircraft from shore airfields because of the excessive erosion of the runway surface. During a short rolling take-off or an ultra-short





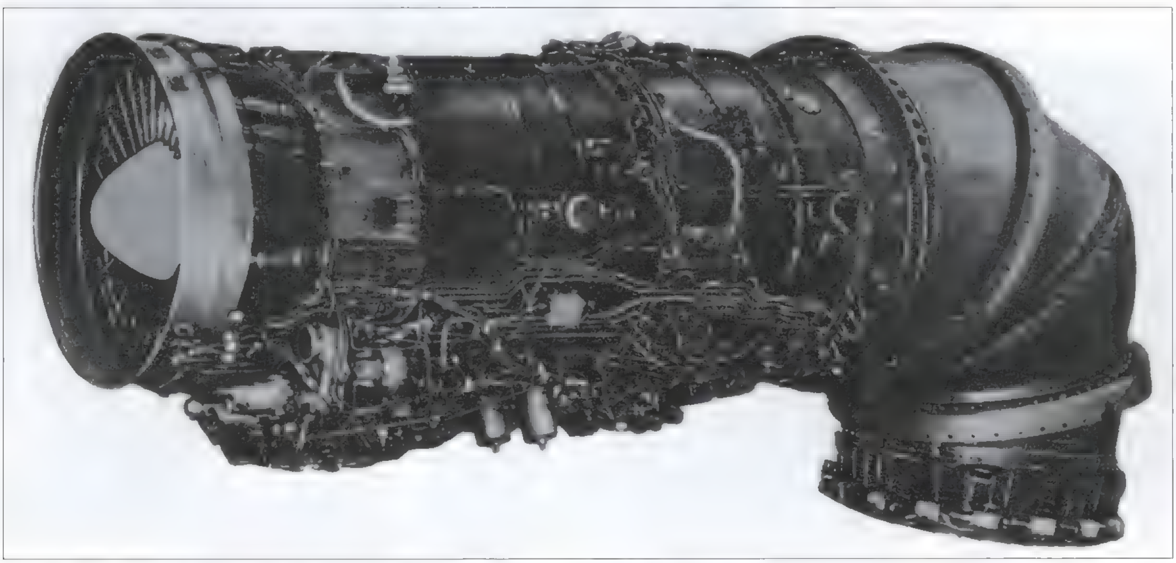
Above: The port main gear unit with its externally located retraction ram. Right: The nose gear unit features a remarkably small wheel.



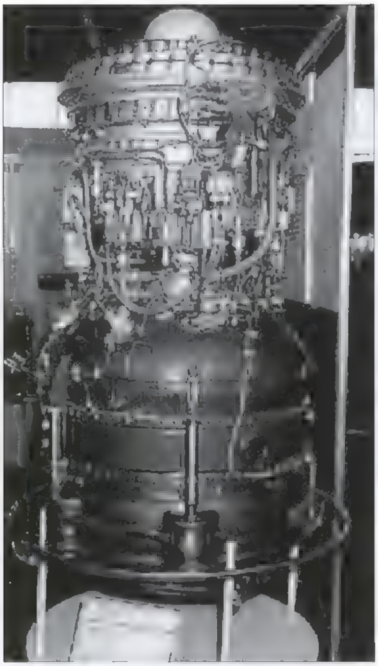
**Above: The lift engine air intake door of the first prototype. The spring-loaded suction relief doors have been removed and the engine inlets are closed by blanks.
Right and top right: The nozzle of the R79V-300 lift/cruise engine. The fairings above it accommodate the brake parachute (on the centreline) and the FDR.
Far right: The 'snap-action' nozzle door of the main engine in the open position.**

take-off (a so-called 'pointed start') the normal setting of the lift/cruise engine nozzle was 65° (63°). During a rolling take-off the vectoring of the nozzle was effected after the beginning of the take-off run, and during a 'pointed start' with a take-off run of some 6 m (20 ft) the nozzle of the engine running in afterburner mode was vectored before the aircraft started its movement.

The lift engines can be used up to an altitude of 2,500 m (8,200 ft) at flight speeds not exceeding 550 km/h (342 mph). In vertical take-off/hover mode two transverse recirculation dams are extended beneath the air intakes of the lift/cruise engine in order to prevent ingestion of exhaust gases (from the area of the upward flow formed between the jet effluxes of the lift engines and the lift/cruise



The Kobchenko (AMNTK Soyuz) R79V-300 lift/cruise engine. The nozzle is at maximum 95° deflection.



Above: The RKBM RD-41 lift engine.

engine) and ingestion of foreign objects; they are assisted by two longitudinal horizontal strakes on the centre fuselage sides separating the hot gas efflux from the fuselage.

During the transition from vertical to horizontal flight the pilot manually reduces the thrust vectoring angle of the lift/cruise engine to 65° (63°); further change of the thrust vectoring angle to 0° was effected automatically. The thrust of the lift engines was reduced automatically, preventing the aircraft from getting out of trim in the course of the entire transition to horizontal flight.

Control system: In cruise flight, control of the aircraft in pitch, roll and yaw was effected by means of traditional control surfaces (stabilators, ailerons and rudders). In the hover and in low-speed flight it was performed by reaction control jets (puffers) located at the wingtips (for roll control) and the tips of the tailbooms (for yaw; first prototype only), as well as by the differential change of the thrust of lift engines and the lift/cruise engine (for pitch). The second prototype had one puffer under the nose instead of two at the rear. The air for the reaction control puffers was bled from the lift/cruise engine.

The control surfaces and reaction control puffers were governed by a digital fly-by-wire control system with full authority and triple redundancy. A back-up mechanical control system was also available.

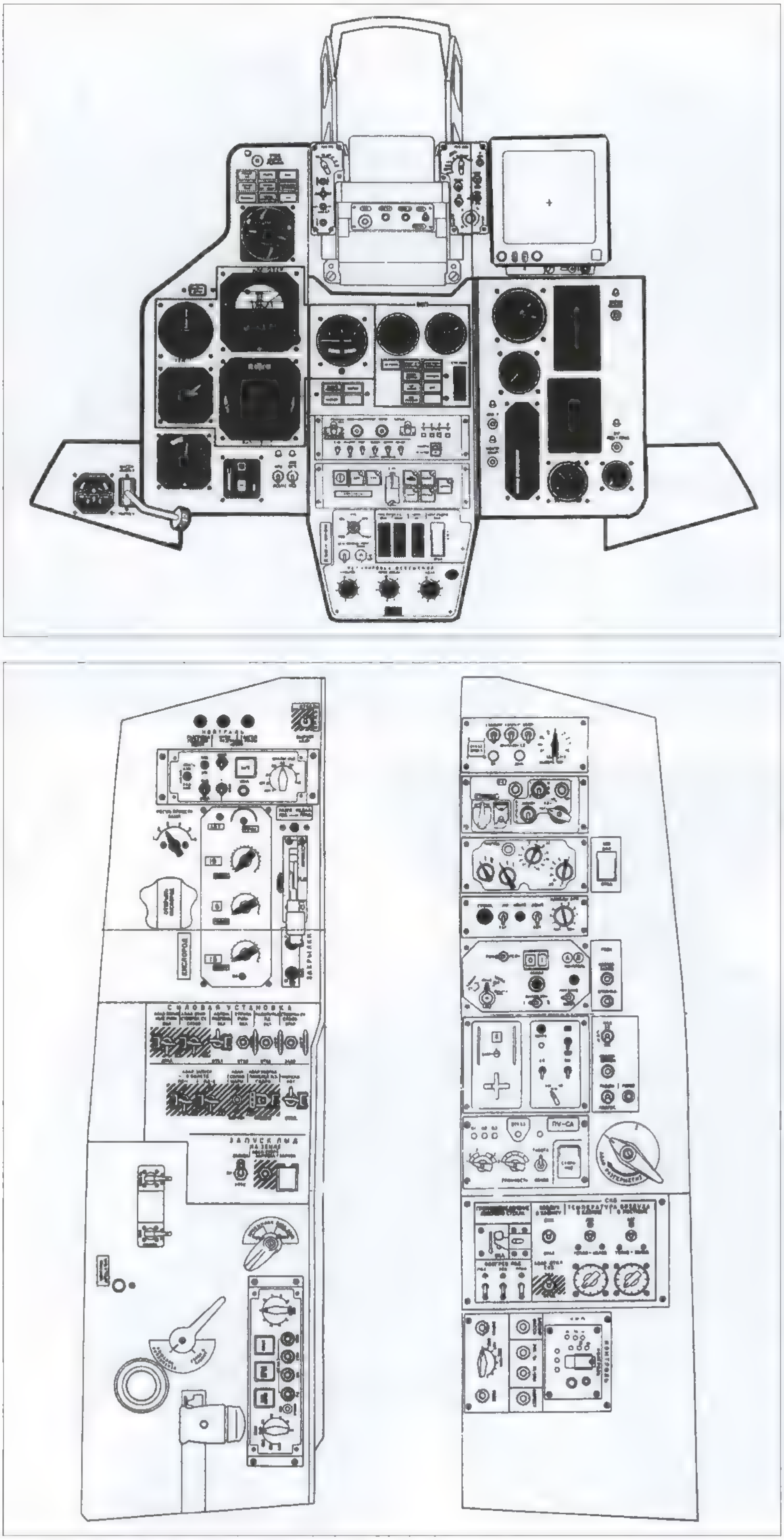
One of the three prototypes was provided with an analogue FBW control system instead of a digital one and featured no mechanical back-up.

Fuel system: The fuel system ensures fuel feed to the engines in all flight modes. All internal fuel is housed in the fuselage; provision is made for carrying drop tanks under the wings. To enhance the reliability of the fuel system at high altitudes, the fuel tanks and fuel accumulators (the latter ensure uninterrupted engine operation in zero- and negative-G conditions) are pressurised by air bled from the lift/cruise engine.

The maximum internal fuel load is 4,400 kg (9,700 lb). Provision is made for installing a conformal fuel tank holding 1,750 litres (385 Imp gal).

Hydraulics and pneumatics: The hydraulic system comprises two autonomous systems: the power control system and the general one. The pneumatic system also comprises two autonomous systems: the power control system and the emergency system.

The rather provisional instrument panel of the first prototype surmounted by a head-up display.



The instrument panel and lateral cockpit consoles of the Yak-41.

Air conditioning and pressurisation system: The air conditioning system ensured the maintenance of the required temperature and air pressure in the cockpit in all flight modes and at all altitudes, as well as the ventilation of the protective equipment and air feed to the chambers of the anti-g suit.

Avionics and equipment. The flight and navigation suite ensures manual, flight director and automatic control of the aircraft all the way from take-off to landing at any time of day and night in visual or instrument meteorological conditions at all geographical latitudes. The flight and navigation suite comprises:

- an inertial navigation system;
- an automatic control system;
- a SHORAN/approach system;
- a radio altimeter;
- an automatic direction finder;
- a satellite navigation system.

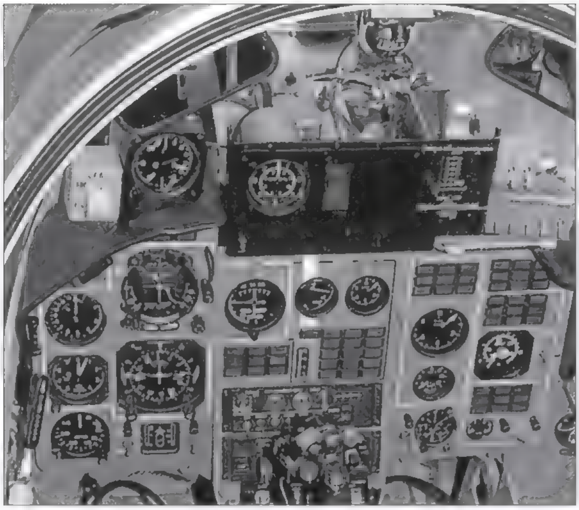
The navigation/attack suite comprises the S-41M weapons system incorporating the Phazotron Zhuk multi-mode pulse-Doppler fire control radar (in the M002 version featuring slightly smaller dimensions as compared to those of the version installed on the MiG-29M), a weapons control system and a laser/TV guidance system, a multi-function display and a head-up display. The radar is capable of detecting aerial targets with a radar cross-section area of 3 m^2 (32.29 sq ft) at a distance of up to 80 km (50 miles) and small surface vessels at a distance of up to 110 km (68 miles). Provisions are made for fitting the aircraft with an infrared a search & track (IRST) system coupled with the radar and a laser rangefinder.

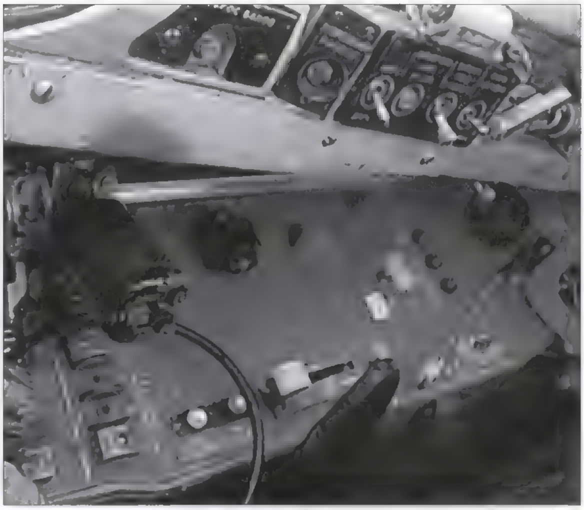
The WCS makes it possible to attack several targets at a time and to perform ground mapping with high resolution. The aiming avionics suite incorporates a digital computer around which its aforementioned elements are clustered.

The flight and navigation suite makes it possible to determine the aircraft's co-ordinates in flight with the help of both ship-based radio systems and satellite navigation systems. The avionics suite includes systems for remote control and director control of the aircraft, an autonomous navigation computer and other devices.

Electronic countermeasures equipment is housed in the wingtips and fin tips. The strakes extending forward from the fins can house chaff/flare dispensers.

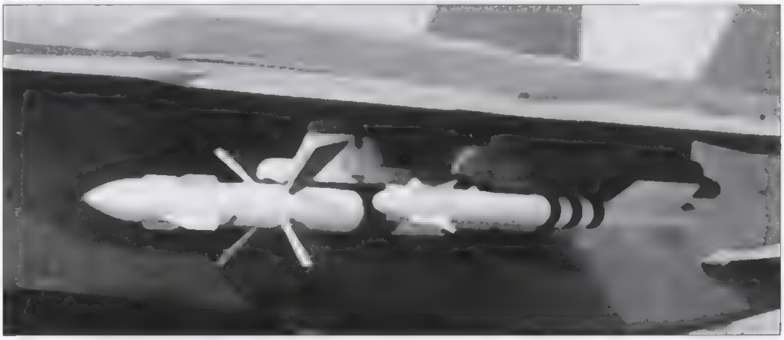
Armament: The built-in armament comprises a single 30-mm (1.18 calibre) Gryazev/Shipunov GSh-301 cannon partially buried in the centre fuselage underside, offset to port. The cannon has a complement of 120 rounds of various types, ensuring the destruction of lightly armoured aerial and ground (or





Above: The cockpit of this Yak-41 shows a very different instrument panel and lacks the HUD. Note the rear view mirrors.

Above right: The port control console with a common sliding throttle for the three engines.



Right: Dummy R-27R and R-73 AAMs under the port wing of the first prototype.

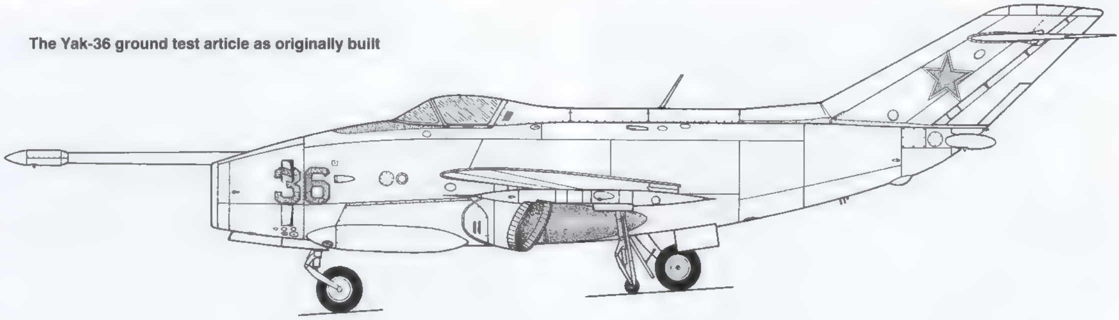
sea surface) targets. Additionally, the Yak-41 can carry a maximum ordnance load of 2,600 kg (5,730 lb) on four pylons under the wings. The armament options depend on the type of targets to be engaged and are divided into three main groups: short-range AAMs (the Vympel R-73 and R-60/R-60M IR-homing missiles), medium-range AAMs (the Vympel R-77 active radar-homing AAM and the Vympel R-27R/R-27T with SARH and IR seeker heads respectively), and air-to-surface missiles (Zvezda Kh-31A anti-shipping missiles, Kh-31P anti-radar missiles, Kh-25 air-to-surface missiles and other types). Provision is made for a sufficiently wide range of unguided rockets and bombs. The aircraft can also carry UPK-23-250 cannon pods housing a 23-mm (.90 calibre) GSh-23 cannon with 250 rounds; other options are FFAR pods for rockets with a calibre of 80 to 240 mm (3.15 to 9.45 in), as well as up to six 500-kg (1,100-lb) bombs.

Emergency escape system: The pilot escape system based on the Zvezda K-36V zero-zero ejection seat ensures automatic escape from the aircraft in vertical and transition flight modes in an emergency. This system is armed automatically when the nozzle of the lift/cruise engine is vectored to an angle exceeding 30°. Compulsory automatic ejection of the pilot is effected when the aircraft exceeds a certain preselected pitch angle or a preselected combination of bank angle and roll rate.

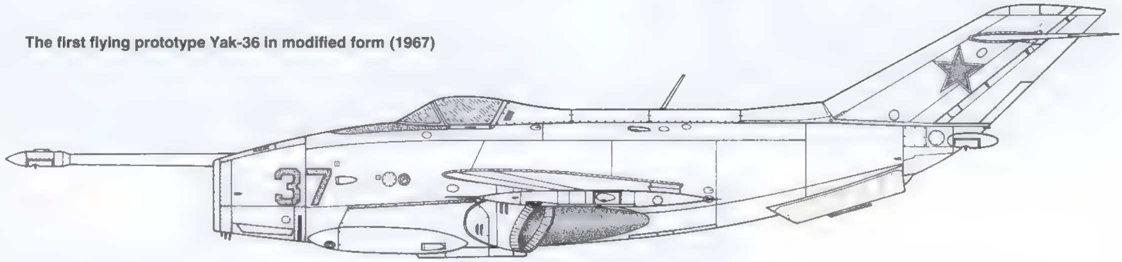
Specification of the Yak-41M (Yak-141)

Length overall	18.3 m (60 ft 0½ in)
Height on ground	5.0 m (16 ft 4¾ in)
Wing span, m (ft):	
when fully deployed	10.1 m (33 ft 1¾ in)
when folded	n.a.
Wing area, m² (sq ft)	31.7 (341.25)
Empty equipped weight, kg (lb)	11,650 (25,688)
Maximum take-off weight, kg (lb):	
at a take-off run of 120 m (390 ft)	19,500 (43,000)
at a vertical take-off	15,800 (34,840)
Maximum external stores load, kg (lb):	
at a take-off run of 120 m (390 ft)	2,600 (5,730)
at a vertical take-off	1.000 (2,205)
Maximum fuel load, kg (lb):	
internal	4,400 (9,700)
in the drop tanks	1,750 (3,750)
Maximum level flight speed, km/h (mph):	
at sea level	1,250 (777)
at 11,000 m (36,080 ft)	1,800 (1,119)
Service ceiling, m (ft)	15,000 (49,200)
Practical range after vertical take-off without external stores, km (miles):	
at an altitude of 10-12 km (32,800-39,370 ft)	1,400 (870)
at sea level	650 (404)

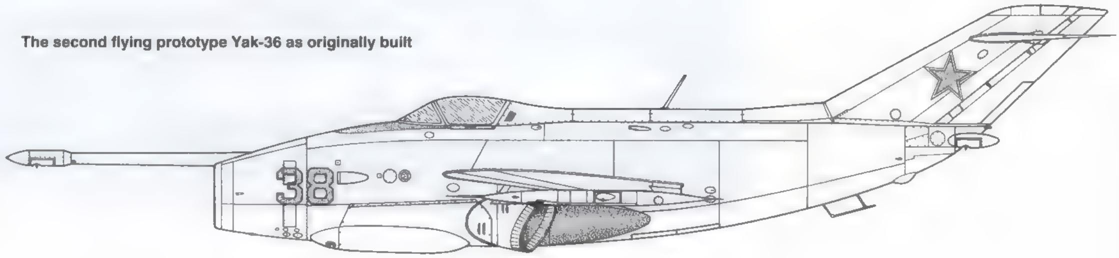
The Yak-36 ground test article as originally built



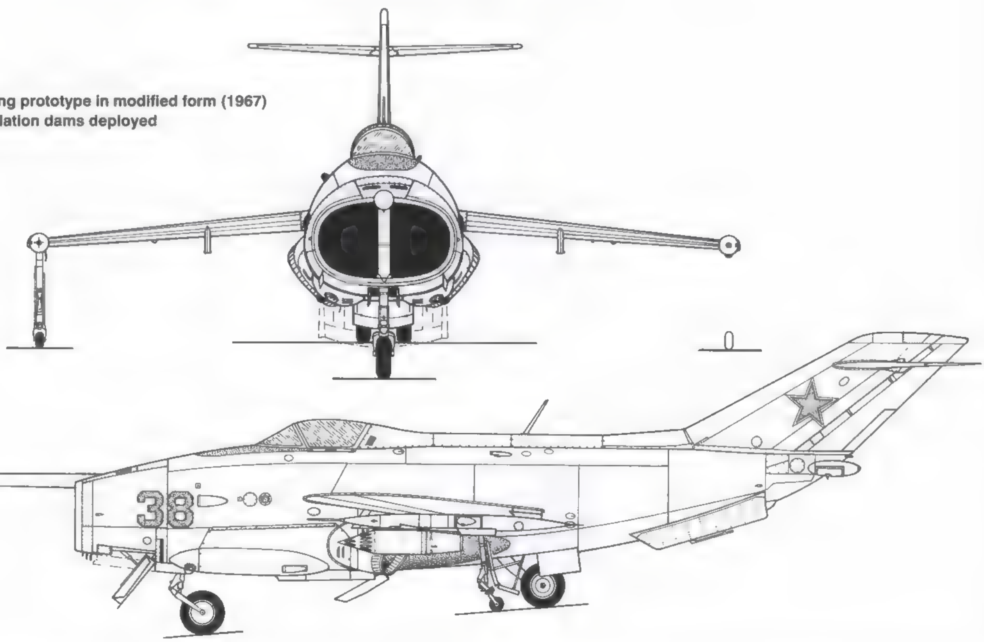
The first flying prototype Yak-36 in modified form (1967)



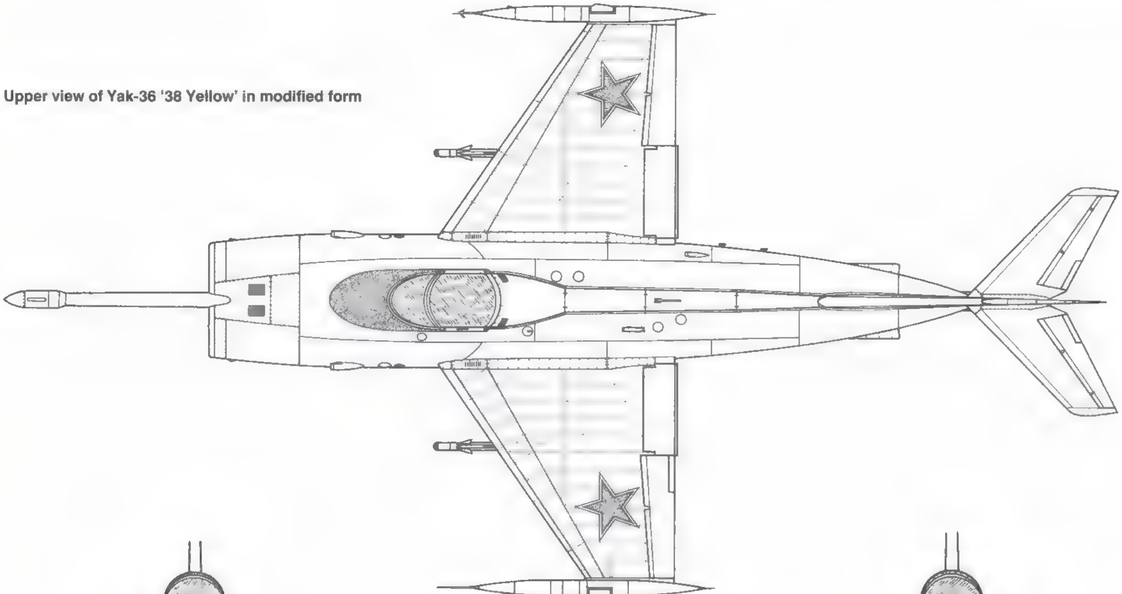
The second flying prototype Yak-36 as originally built

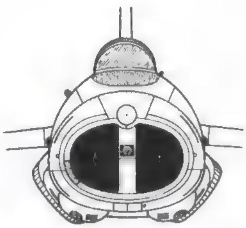


The second flying prototype in modified form (1967)
with the recirculation dams deployed

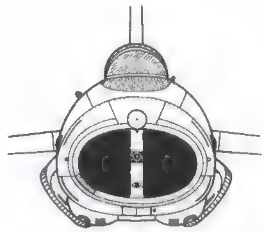


Upper view of Yak-36 '38 Yellow' in modified form

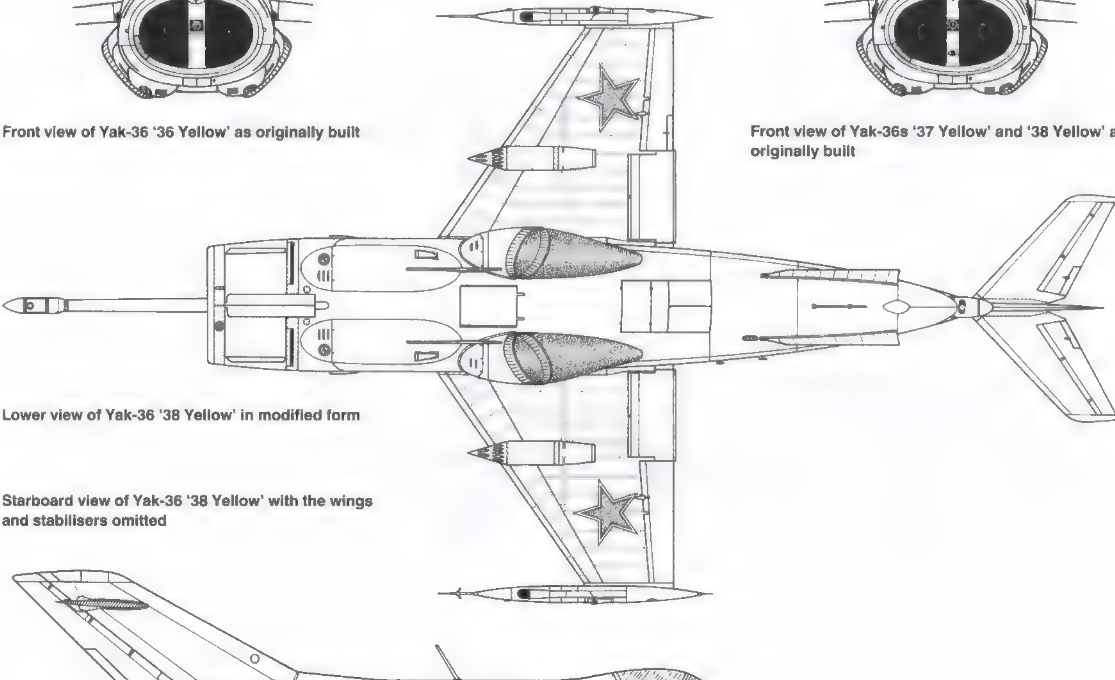




Front view of Yak-36 '36 Yellow' as originally built

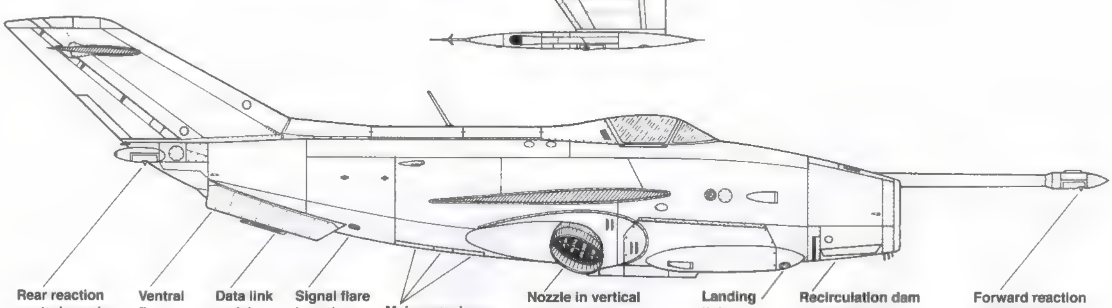


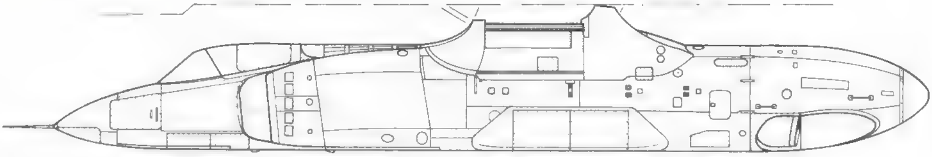
Front view of Yak-36s '37 Yellow' and '38 Yellow' as originally built



Lower view of Yak-36 '38 Yellow' in modified form

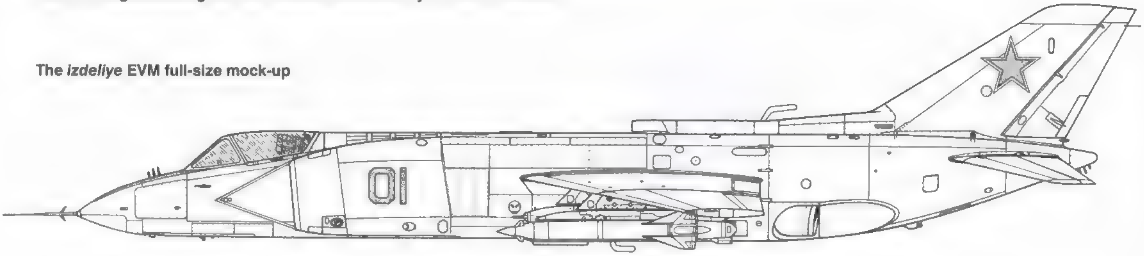
Starboard view of Yak-36 '38 Yellow' with the wings and stabilisers omitted



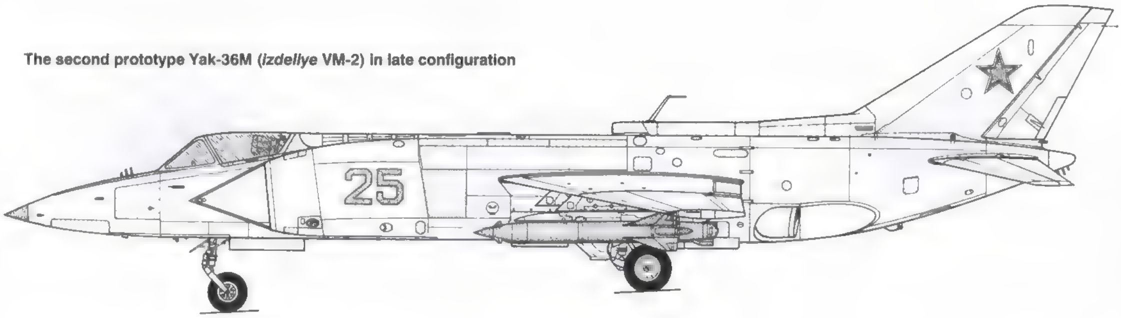


The DLL engine test rig for the Yak-36M as carried by Tu-16LL '02 Blue'

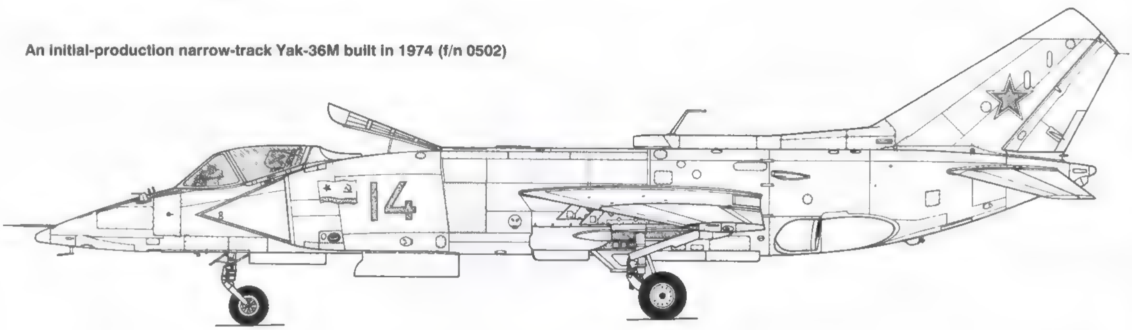
The *izdeliye* EVM full-size mock-up



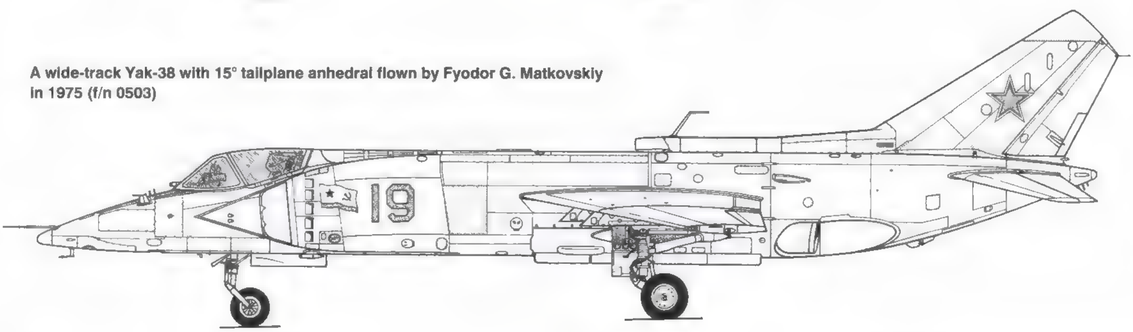
The second prototype Yak-36M (*izdeliye* VM-2) in late configuration



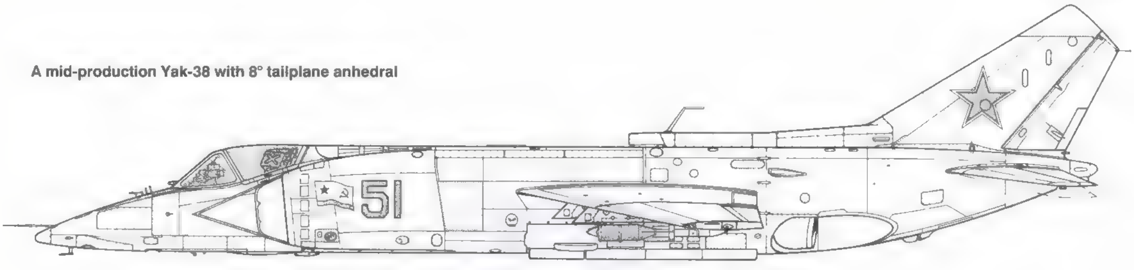
An initial-production narrow-track Yak-36M built in 1974 (f/n 0502)



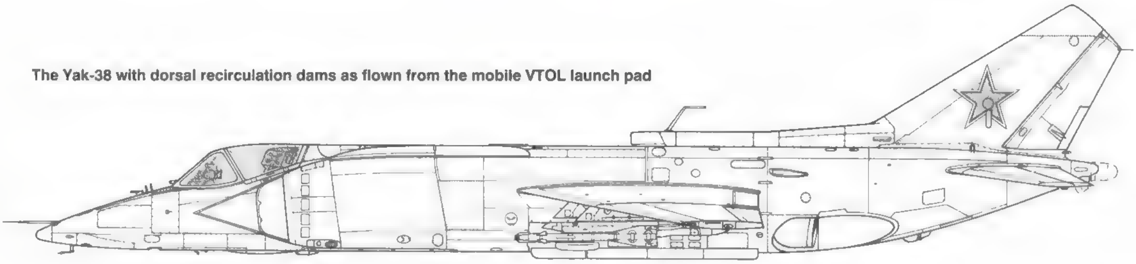
A wide-track Yak-38 with 15° tailplane anhedral flown by Fyodor G. Matkovskiy in 1975 (f/n 0503)



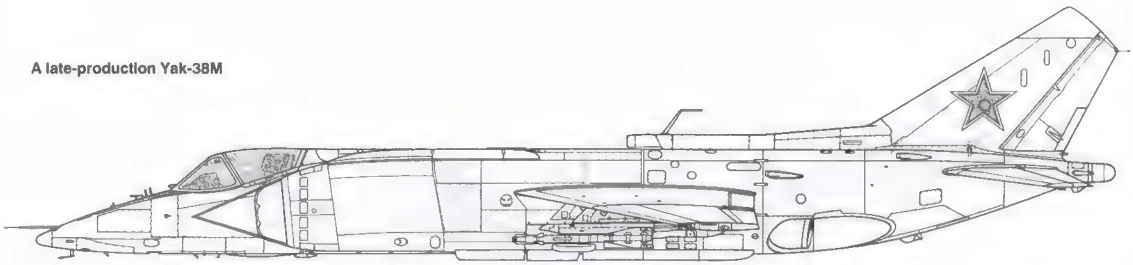
A mid-production Yak-38 with 8° tailplane anhedral



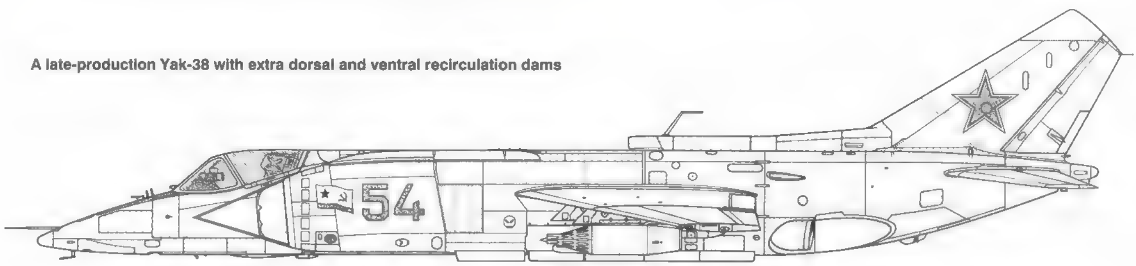
The Yak-38 with dorsal recirculation dams as flown from the mobile VTOL launch pad



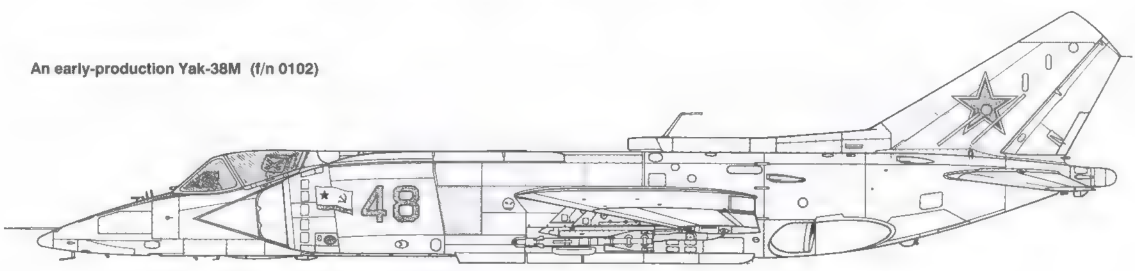
A late-production Yak-38M

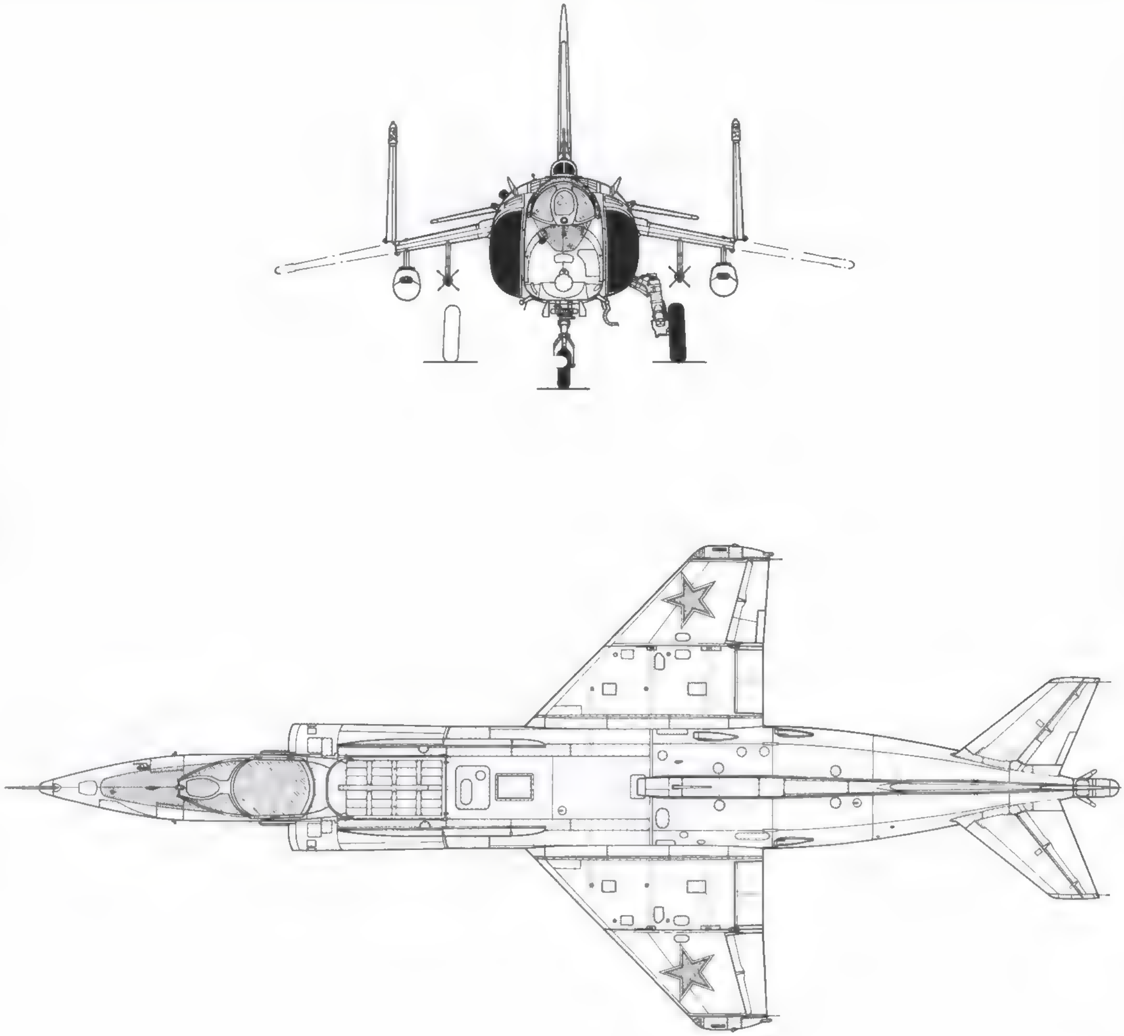


A late-production Yak-38 with extra dorsal and ventral recirculation dams

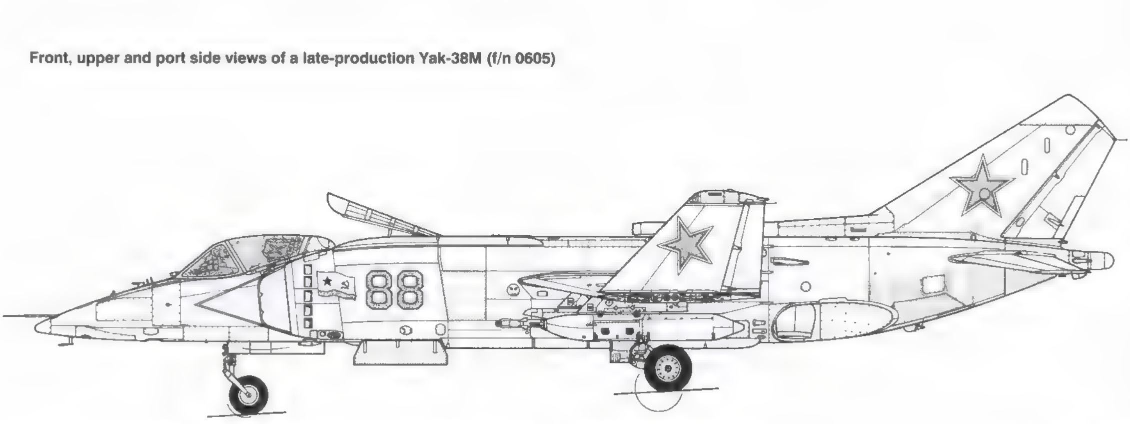


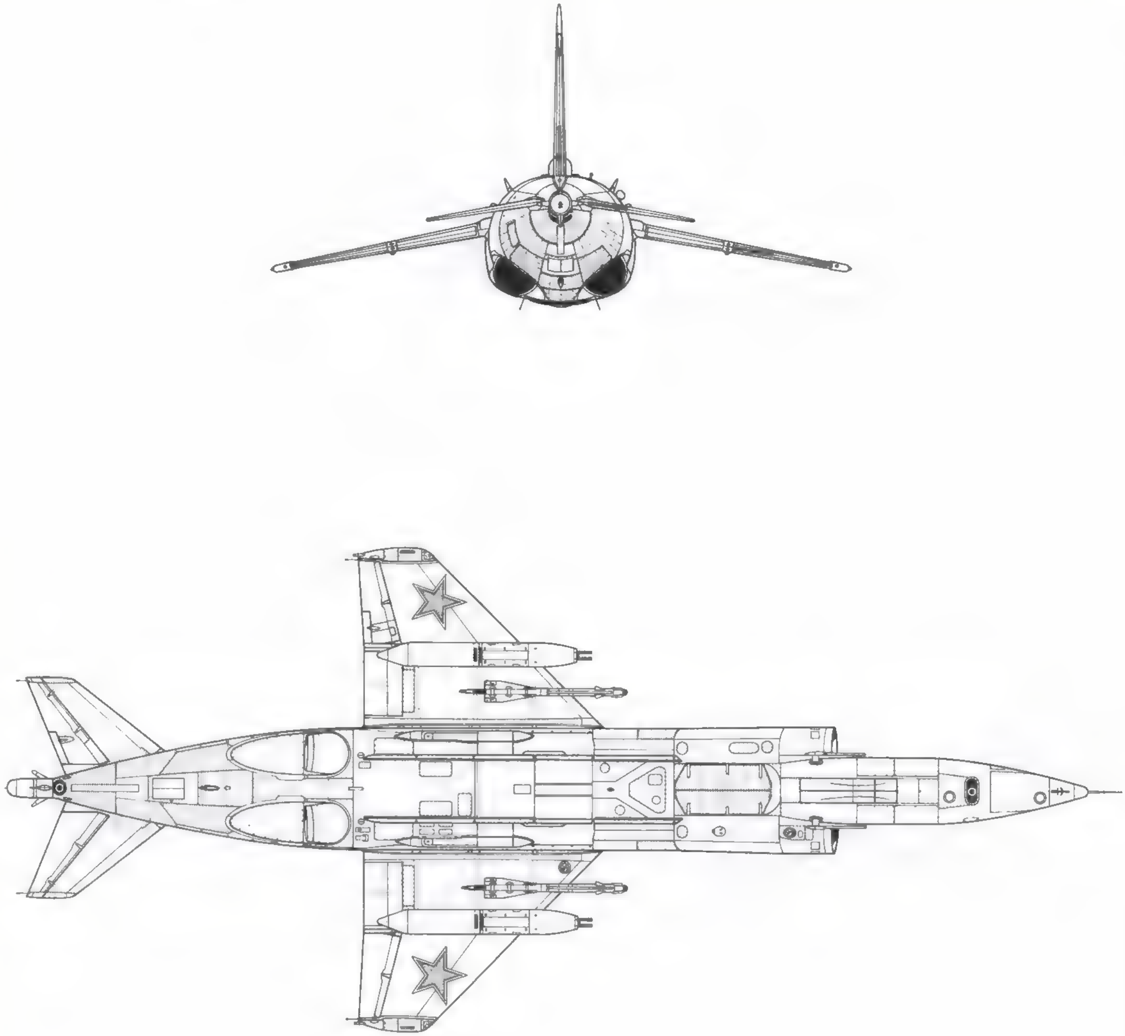
An early-production Yak-38M (f/n 0102)



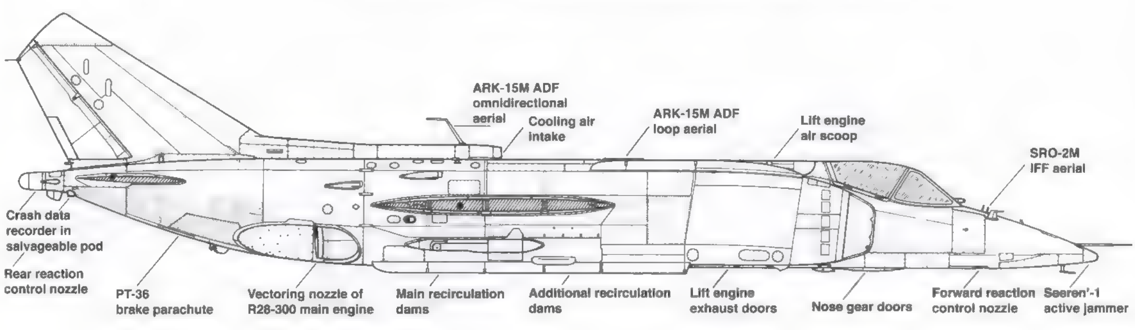


Front, upper and port side views of a late-production Yak-38M (f/n 0605)

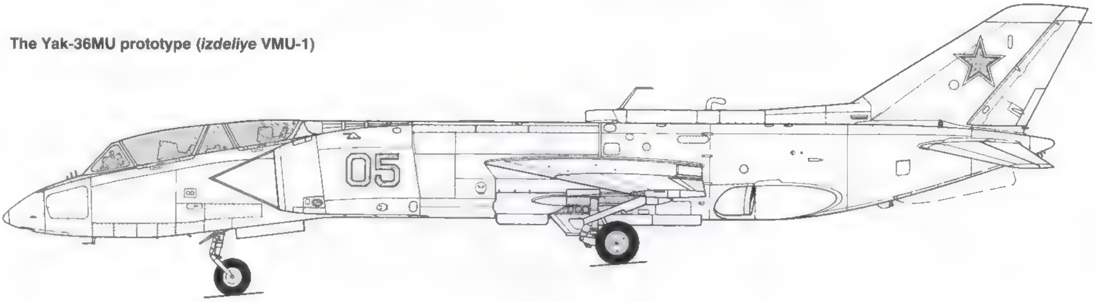




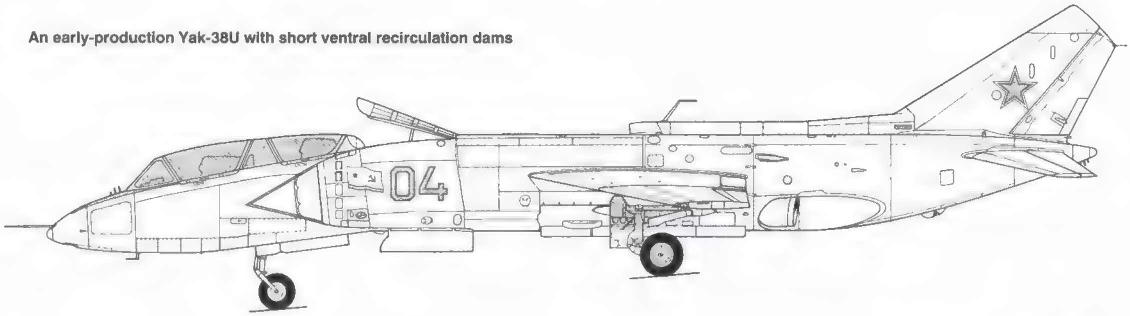
Rear, lower and starboard side view of a late-production Yak-38M (f/n 0605)



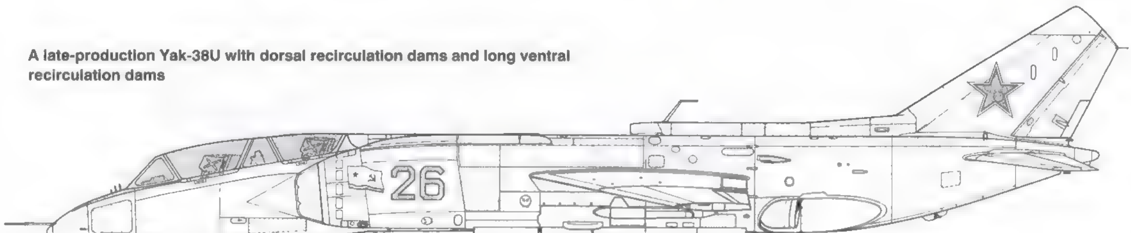
The Yak-36MU prototype (*izdeliye* VMU-1)



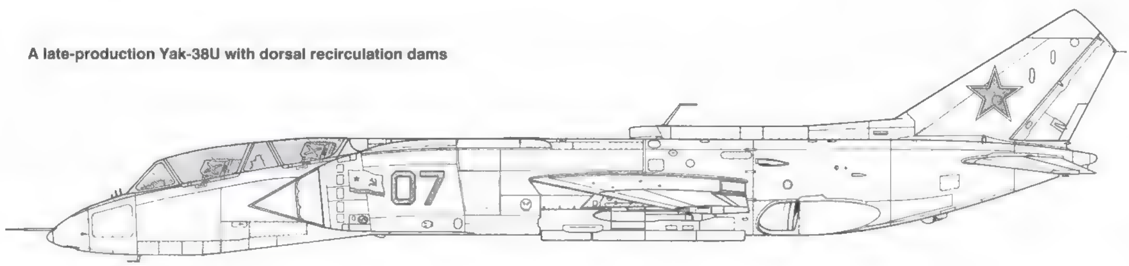
An early-production Yak-38U with short ventral recirculation dams



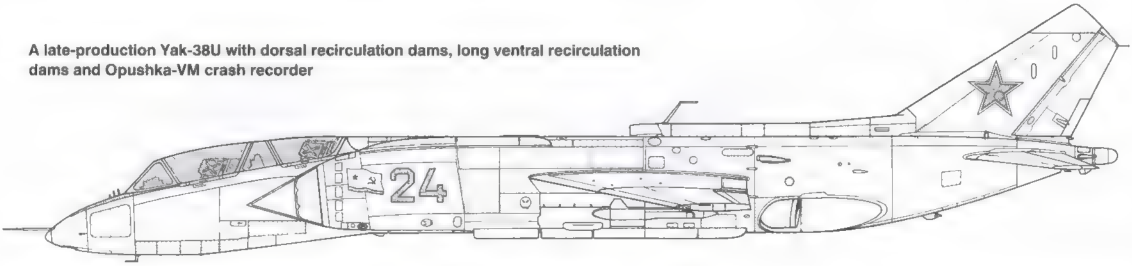
A late-production Yak-38U with dorsal recirculation dams and long ventral recirculation dams



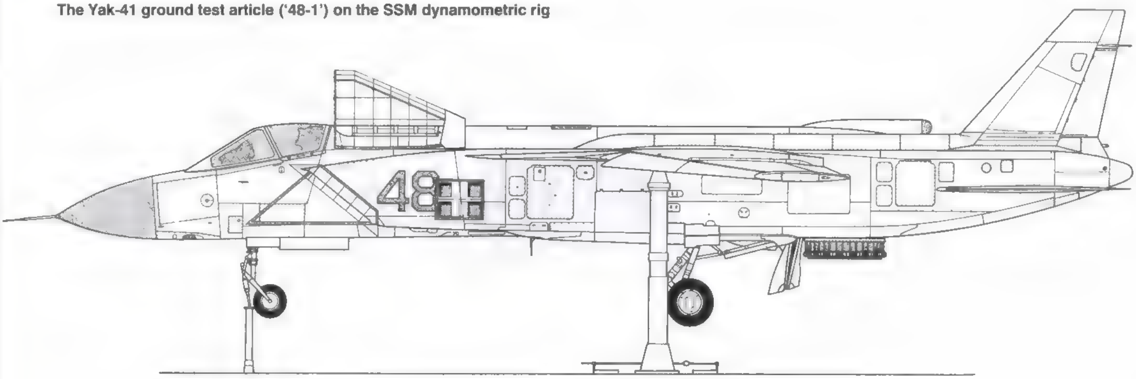
A late-production Yak-38U with dorsal recirculation dams



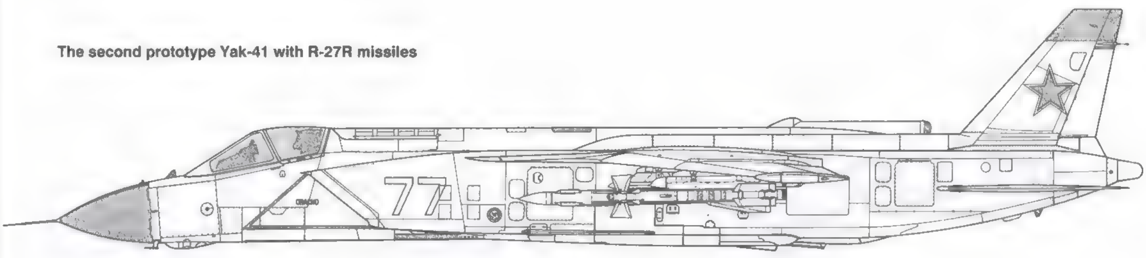
A late-production Yak-38U with dorsal recirculation dams, long ventral recirculation dams and Opushka-VM crash recorder



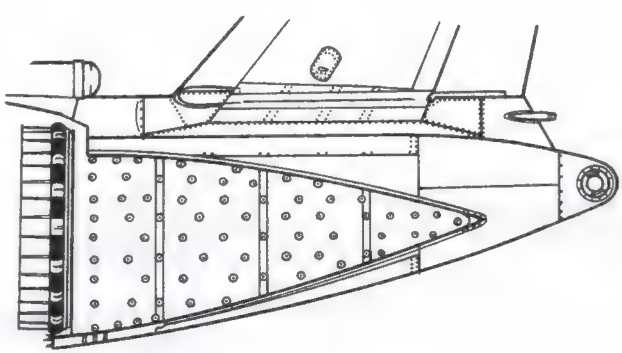
The Yak-41 ground test article ('48-1') on the SSM dynamometric rig

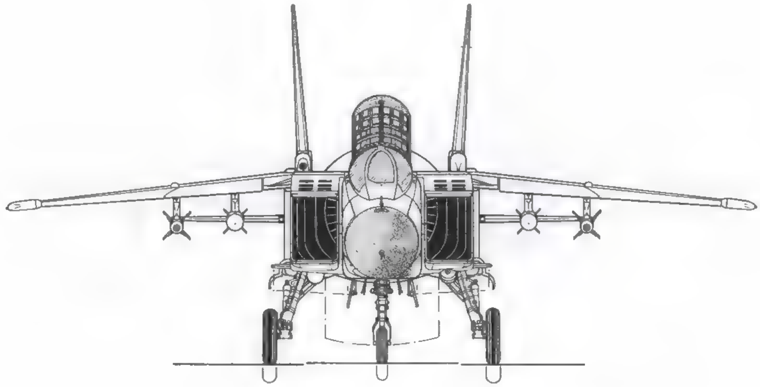


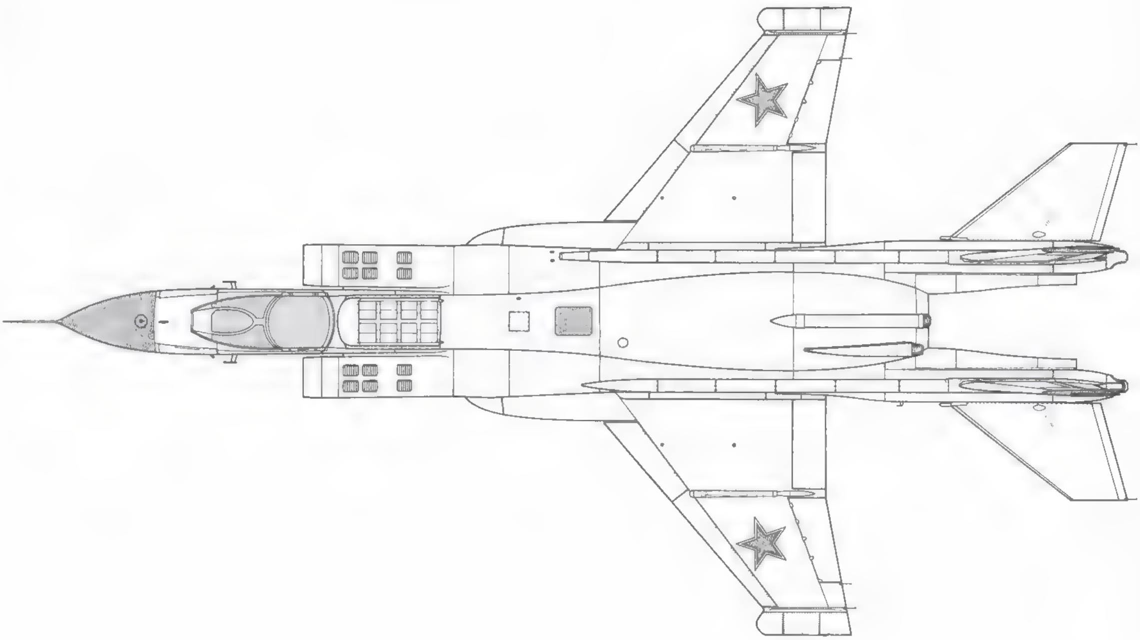
The second prototype Yak-41 with R-27R missiles



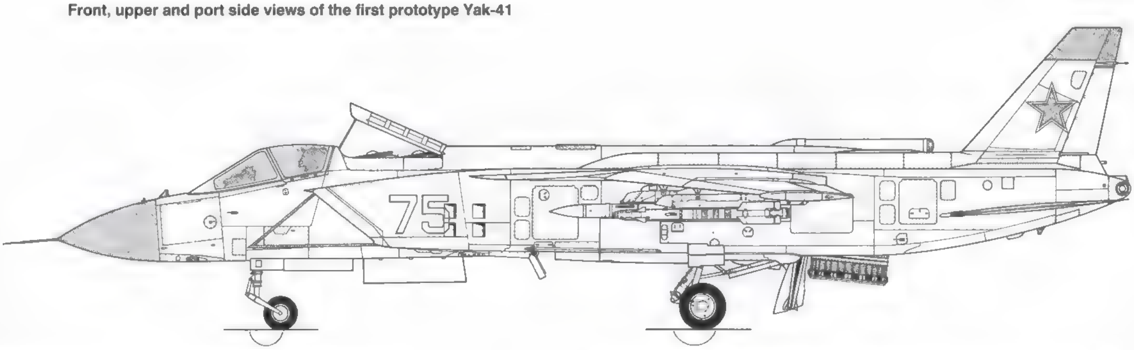
Inner face of starboard tailboom with heat shield

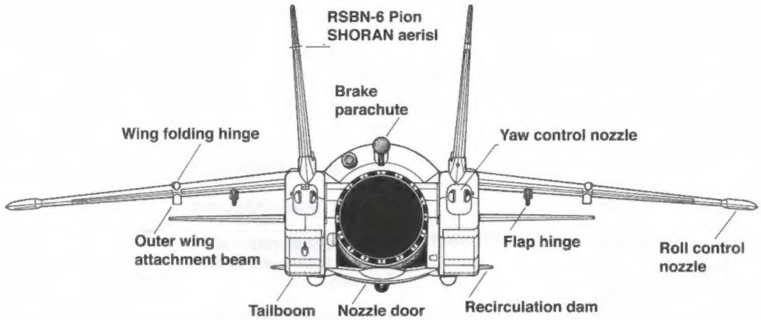


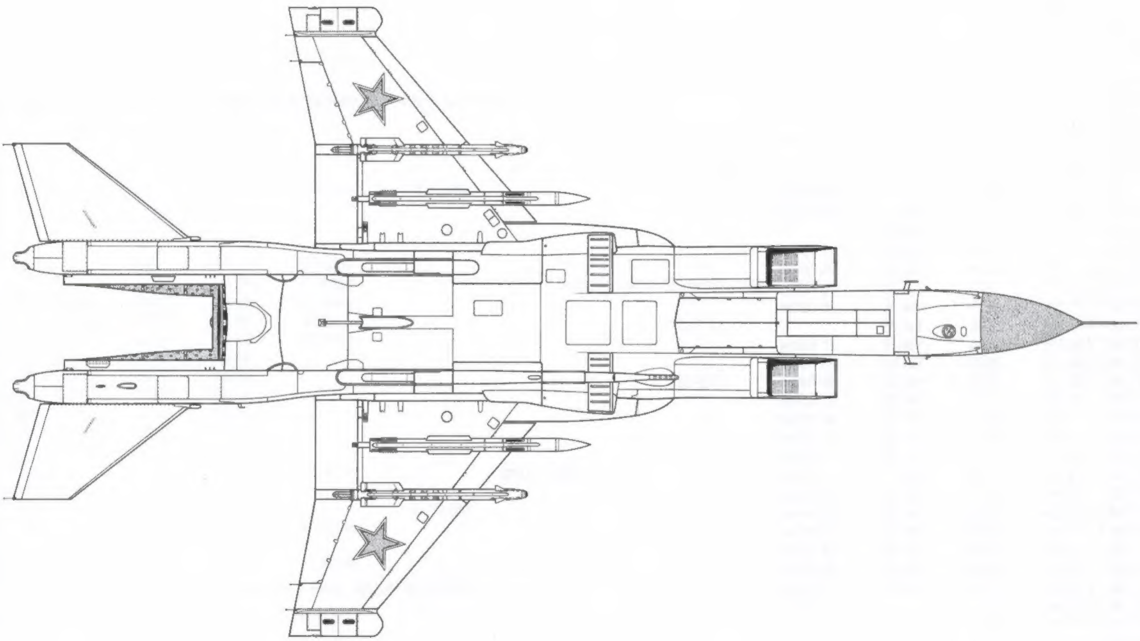


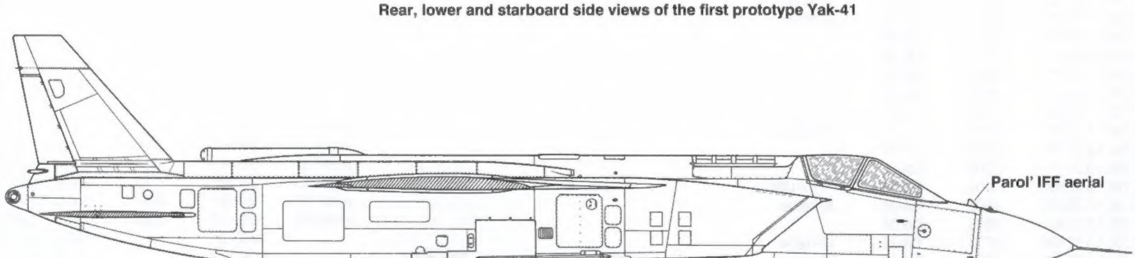


Front, upper and port side views of the first prototype Yak-41









Rear, lower and starboard side views of the first prototype Yak-41

Production list

Known Yak-38s identified by construction number and/or fuselage number are listed here. The 'split' presentation of the c/ns is for the sake of convenience only. Crashed aircraft are marked by 'RIP crosses' followed by the date of the accident (where known).

C/n	F/n	Version	Tactical code	Manufacture date	Notes
01		Yak-36M	05 Yellow		VM-1
02		Yak-36M	25 Yellow		VM-2
03		Yak-36M	55 Yellow		VM-3
04		Yak-36M	45 Yellow		VM-4; to Moscow Aviation Institute as instructional airframe
797.786.*.3.01.001?	0101	Yak-38	03 Yellow		
797.786.*.3.01.0**	0201	Yak-38	no code		Preserved Yakovlev OKB museum
797.786.*.3.01.0**	0301	Yak-38			
797.786.1.4.01.0**	0102	Yak-38	10 Yellow		Gate guard Severomorsk-3 AB
797.786.*.4.01.035	0202	Yak-38	11 Yellow		Static test airframe, later GIA Saki
797.786.*.4.01.102	0302	Yak-38	no code?		† 4-4-1975
797.786.*.4.01.103	0402	Yak-38	12 Yellow		
797.786.4.4.01.137	0502	Yak-38	14 Yellow		Preserved Central Russian AF Museum, Monino (now as '37 Yellow')
797.786.4.4.02.171?	0103	Yak-38	15 Yellow, 07 Yellow		
797.786.4.4.02.205?	0203	Yak-38	16 Yellow		† 7-6-1977
797.786.1.5.02.239?	0303	Yak-38	17 Yellow		
797.786.*.5.02.273	0403	Yak-38	18 Yellow, 07 Yellow		GIA Riga technical school
797.786.*.5.02.307	0503	Yak-38	19 Yellow		
797.786.*.5.02.341?	0603	Yak-38	20 Yellow		† 6-6-1977
797.786.*.5.02.375	0703	Yak-38	23 Yellow		
797.786.*.5.02.409	0803	Yak-38	21 Yellow		
797.786.1.6.02.443	0903	Yak-38	no code	1976	† 4-3-1976
797.786.*.5.02.477	1003	Yak-38	22 Yellow		
797.786.4.5.03.511	0104	Yak-38	46 Yellow		GIA Vasil'kov technical school, now preserved Ukrainian State Aviation Museum, Kiev-Zhulyany
797.786.1.6.03.545?	0204		24 Yellow		
797.786.*.6.03.613	0304?		27 Yellow (!)		† 15-12-1977
797.786.*.6.0*.6**	0404	Yak-38			
797.786.*.6.05.647	0504	Yak-38	27 Yellow, 31 Yellow		
797.786.*.6.05.681	0604	Yak-38	28 Yellow	1976	
797.786.*.6.05.715	0704?	Yak-38	29 Yellow		
797.786.*.6.0*.7**	0804	Yak-38			
797.786.4.6.05.783	0904?	Yak-38	31 Yellow		
797.786.4.6.0*.***	1004	Yak-38	24 Yellow		
797.786.4.6.0*.***	0105	Yak-38	25 Yellow		
797.786.1.7.0*.***	0205	Yak-38	26 Yellow		
797.786.1.7.06.107	0305	Yak-38		13-7-1977	
797.786.*.7.06.115	0405	Yak-38	21 Yellow		
797.786.2.7.06.119	0505	Yak-38	28 Yellow		
797.786.2.7.06.147	0605	Yak-38	29 Yellow	13-6-1977	
797.786.2.7.06.169	0705	Yak-38	31 Yellow		
797.786.*.7.07.180	0805	Yak-38	32 Yellow		
797.786.*.7.07.204	0905	Yak-38	32 Yellow (!)		
797.786.*.7.07.210	1005	Yak-38	33 Yellow		
797.786.*.7.14.230	0106	Yak-38	34 Yellow		† 26-10-1978
797.786.*.7.14.247	0206	Yak-38	35 Yellow		
797.786.4.7.14.289	0306	Yak-38	36 Yellow		
797.786.*.7.1*.2**	0406	Yak-38	37 Yellow		
797.786.*.7.1*.3**	0506	Yak-38	38 Yellow		
797.786.*.7.16.315	0606?	Yak-38	39 Yellow		† ?-7-1980
797.786.*.8.16.323	0706?	Yak-38	11 Yellow		Preserved Central Russian AF Museum, Monino (now as '38 Yellow')
797.786.2.8.16.340	0806	Yak-38	40 Yellow	20-6-1978	
797.786.*.8.**.3**	0906	Yak-38	41 Yellow		
797.786.*.8.**.3**	1006	Yak-38	42 Yellow		
797.786.3.8.22.366	0107	Yak-38	43 Yellow, 23 Yellow		
797.786.3.8.22.372	0207	Yak-38	44 Yellow	30-10-1978	† 30-9-1980
797.786.3.8.22.377	0307	Yak-38	45 Yellow	12-10-1978	† 8-9-1980
797.786.3.8.22.385	0407	Yak-38	46 Yellow		
797.786.*.*.30.400	0507	Yak-38	22 Yellow		
797.786.*.*.30.4**	0607?	Yak-38			
797.786.*.*.30.4**	0707?	Yak-38			
797.786.*.*.30.4**	0807?	Yak-38			
797.786.*.*.30.4**	0907?	Yak-38			
797.786.*.*.30.451	1007?	Yak-38	52 Yellow?		
797.786.*.*.30.470	0108?	Yak-38	53 Yellow		
797.786.4.8.3*.***	0208?	Yak-38			
797.786.1.9.3*.***	0308?	Yak-38			
797.786.*.9.33.502	0408?	Yak-38	?? † 7-1980		
797.786.*.9.33.570	0508	Yak-38	35 Yellow		
797.786.*.9.33.601	0608	Yak-38			
797.786.*.9.33.606	0708	Yak-38	58 Yellow		
797.786.*.9.33.612	0808	Yak-38	57 Yellow		
797.786.*.9.40.624	0908	Yak-38	55 Yellow		
797.786.2.9.40.627	1008	Yak-38	56 Yellow	20-4-1979	† 6-7-1981
797.786.*.9.47.630	0109	Yak-38			
797.786.*.9.47.633	0209	Yak-38	51 Yellow	5-2-1980	† 27-5-1981
797.786.*.9.47.646	0309?	Yak-38			
797.786.*.9.47.649	0409?	Yak-38			

797.786.4.9.52.651	0509?	Yak-38			
797.786.1.0.52.658	0609?	Yak-38			
797.786.1.0.54.666	0709?	Yak-38	53 Yellow		† 25-7-1983
797.786.*.0.54.678	0809?	Yak-38			
797.786.*.0.**.***	0909	Yak-38	55 Yellow		
797.786.2.0.**.***	1009	Yak-38			
797.786.2.0.**.***	0110	Yak-38			
797.786.2.0.**.***	0210	Yak-38			
797.786.*.0.**.***	0310	Yak-38			
797.786.*.0.**.***	0410	Yak-38			
797.786.3.0.60.683	0510	Yak-38		26-9-1980	
797.786.3.0.60.6**	0610	Yak-38			
797.786.3.0.60.6**	0710	Yak-38			
797.786.3.0.60.6**	0810	Yak-38			
797.786.4.0.60.697	0910	Yak-38		4-2-1982!?	
797.786.4.0.60.699	1010	Yak-38	60 Yellow		Preserved Moscow-Khodynka
797.786.4.0.60.***	0111	Yak-38			
797.786.4.0.60.871	0211?	Yak-38	16 Yellow		
797.786.4.0.6*.***	0311	Yak-38	46 Yellow		
797.786.4.0.63.371	0411	Yak-38		9-3-1981	†
797.786.1.1.**.***	0511	Yak-38			
797.786.*.1.**.***	0611	Yak-38			
797.786.*.1.**.***	0711	Yak-38			
797.786.*.1.**.***	0811	Yak-38			
797.786.*.1.71.590	0911?	Yak-38			
797.786.*.1.**.***	1011	Yak-38			
797.786.*.1.**.***	0112	Yak-38			
797.786.*.1.**.***	0212	Yak-38			
797.786.*.1.74.635	0312	Yak-38	46 Yellow		
797.786.*.1.7*.6**	0412	Yak-38			
797.786.*.1.76.657?	0512?	Yak-38	58 Yellow		
797.786.*.1.7*.6**	0612	Yak-38			
797.786.*.1.7*.6**	0712	Yak-38			
797.786.3.1.78.705	0812	Yak-38		4-11-1981	
797.786.*.1.78.7**	0912	Yak-38			
797.786.4.1.78.729	1012	Yak-38	69 Yellow	18-1-1982	
797.786.4.1.**.***	0113	Yak-38			
797.786.4.1.**.***	0213	Yak-38			
797.786.4.1.81.759	0313?	Yak-38			
	0413	Yak-38M	82 Yellow		First prototype † 12-4-1985
	0513	Yak-38M	83 Yellow		Second prototype; preserved in the Ukraine
797.786.*.2.86.815	0613?	Yak-38	73 Yellow		
797.786.*.2.86.840	0713?	Yak-38	74 Yellow		
797.786.*.2.90.847	0813?	Yak-38	75 Yellow		
797.786.*.2.**.***	0913?	Yak-38			
797.786.*.2.**.***	1013?	Yak-38			
797.786.*.2.**.***	0114?	Yak-38			
797.786.*.2.**.***	0214?	Yak-38			
797.786.*.2.**.***	0314?	Yak-38			
797.786.*.2.**.***	0414?	Yak-38			
797.786.*.2.**.***	0514	Yak-38	84 Yellow		† 10-11-1983
797.786.*.2.**.***	0614	Yak-38			
797.786.3.2.95.881	0714	Yak-38		25-10-1982	
797.786.*.*.97.565		Yak-38	86 Yellow		
797.786.*.*.97.677		Yak-38			
797.786.2.3.97.***	0615	Yak-38	61 Yellow		
797.786.4.3.98.473		Yak-38		27-12-1983	†
797.782.4.4.0*.***	0102	Yak-38M	48 Yellow		
797.782.1.5.04.192	0*02	Yak-38M			
797.782.1.5.04.292	0702	Yak-38M	38 Yellow		
797.782.4.7.08.489	0505	Yak-38M	63 Yellow		
797.782.4.7.08.494	0605	Yak-38M	88 Yellow		
797.782.*.*.**.***		Yak-38M	99 White		
01		Yak-36MU	05 Yellow		
797.776.*.5.0*.0**	0101	Yak-38U			
797.776.4.5.05.037	0201?	Yak-38U	01 Yellow	1975	Preserved Lugansk museum, the Ukraine
797.776.3.6.11.071	0102	Yak-38U		18-10-1976	
	0202	Yak-38U			Static test airframe
	0302	Yak-38U	06 Yellow?		
797.776.*.*.13.173	0103	Yak-38U	07 Yellow		
797.776.3.7.13.243	0203	Yak-38U	08 Yellow	29-10-1977	† 7-6-1979
797.776.1.8.13.264	0303	Yak-38U	09 Yellow	7-2-1978	† 27-12-1979
797.776.*.*.13.303	0403	Yak-38U	07 Yellow		
797.776.*.*.13.355	0503	Yak-38U	04 Yellow		
797.776.*.*.20.346		Yak-38U			
797.776.2.0.38.454		Yak-38U		26-6-1980	† 16-4-1986
797.776.4.1.**.***	0207	Yak-38U	07 Yellow		
797.776.4.1.48.236	0307?	Yak-38U	24 Yellow		
797.776.*.*.48.271	0407	Yak-38U			
797.776.*.*.54.170		Yak-38U			
797.776.*.*.55.215		Yak-38U	47 Yellow		

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